HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

Teacher Interventions in Students' Joint Work in a Novel Design and Making Environment

University of Helsinki
Faculty of Educational Sciences
Department of Teacher Education
Class Teacher Education
Master's Thesis
Educational Science
June 2018
Helmi-Riikka Olkinuora

Supervisors: Kristiina Kumpulainen, Anu Kajamaa & Antti Rajala

UNIVERSITY OF HELSINKI

Tiedekunta - Fakultet - Faculty Faculty of Educational Sciences		
Tekijä - Författare - Author Helmi-Riikka Olkinuora		
Title Teacher Interventions in Students' Joint Work in a Novel Design and Making Environment		
Työn nimi - Arbetets titel Opettajainterventiot oppilaiden keskinäiseen työskentelyyn uudessa digitaalisessa maker-oppimisympäristössä		
Oppiaine - Läroämne - Subject Education		
Työn laji/ Ohjaajat - Arbetets art/Handledare - Level/Instructors Master's Thesis / Kristiina Kumpulainen, Anu Kajamaa & Antti Rajala	Aika - Datum - Month and year June 2018	Sivumäärä - Sidoantal - Number of pages 74 pp. + 2 appendices

Tiivistelmä - Referat - Abstract

Learning environments in schools are changing into a more learner-centered direction, which changes the roles of both students and teachers. Currently there is not much knowledge about how teachers support students in novel, student-driven learning environments. The aim of this study is to analyze teacher interventions in students' joint work in a novel digital design and making environment. This study examined which kind of situations caused teachers to intervene in students' joint work and which intervention strategies teachers use when intervening. Previous research suggests that teacher interventions can support joint problem solving and improve students' thinking skills (Hofmann & Mercer, 2016; Ding, Li, Piccolo & Kulm, 2007). Maker education in turn promotes students' creative problem-solving (Bevan et al., 2016) and enables the growth of relative expertise that refers to students developing expertise relative to each other through social participation (Stevens et al., 2016).

The data were collected by videoing lessons in a primary school, which had introduced a new design and making environment (called the FUSE Studio) in the fall of 2016. The lessons were held for 9 to 12-year-old students. The data consisted of 85 hours of video material. The video data were analyzed by using the techniques of Jordan and Henderson's (1995) interaction analysis. The intervention strategies of the analyzed teacher interventions were modelled after Hofmann and Mercer's research (2016).

The results indicated that teacher interventions in students' joint work occurred in response to many different situations. A total of 55 intervention episodes were classified into five categories: (1) STEAM-challenge related, (2) disciplinary, (3) material related, (4) technology related, and (5) motivation related interventions. Interventions were initiated by both teachers and students. While STEAM-challenge, material, and technology related interventions were mostly student initiated, disciplinary related interventions were mostly teacher initiated. Motivation related interventions were entirely initiated by teachers. Eight of the intervention episodes were analyzed further to examine the intervention strategies that the teachers were using. The strategies were modelled after Hofmann and Mercer's study (2016) and included: (1) authoritative, (2) initiating, and (3) continuing interactive strategies. Examples of all strategies were found however none of the teachers used purely features of continuing interactive strategies when intervening. Authoritative strategies were found in disciplinary interventions and when guiding students through a new task. Initiating strategies supported by continuing interactive strategies appeared to promote peer collaboration and joint problem solving between students.

Teacher interventions seem to be an effective way of supporting relative expertise within novel, student-driven learning environments as long as the teacher is able to use the appropriate intervention strategies according to the objectives of the learning environments.

Avainsanat - Nyckelord

Opettajainterventiot, interventiostrategiat, maker-pedagogiikka, digitaaliset oppimisympäristöt, yhteinen ongelmanratkaisu, jaettu asiantuntijuus

Keywords

Teacher interventions, intervention strategies, maker education, digital design and making environments, joint problem-solving, relative expertise

Säilytyspaikka - Förvaringsställe - Where deposited

Helsinki University Library – Helda / E-thesis (opinnäytteet) *ethesis.helsinki.fi*

UNIVERSITY OF HELSINKI

Tiedekunta - Fakultet - Faculty
Kasvatustieteellinen tiedekunta

Tekijä - Författare - Author
Helmi-Riikka Olkinuora

Title
Teacher Interventions in Students' Joint Work in a Novel Design and Making Environment

Työn nimi - Arbetets titel
Opettajainterventiot oppilaiden keskinäiseen työskentelyyn uudessa digitaalisessa maker-oppimisympäristössä

Oppiaine - Läroämne - Subject
Kasvatustiede

Työn laji/ Ohjaajat - Arbetets art/Handledare - Level/Instructors	Aika - Datum - Month and year	Sivumäärä - Sidoantal - Number of pages
Pro gradu -tutkielma / Kristiina Kumpulainen, Anu Kajamaa & Antti Rajala	June 2018	74 s. + 2 liitettä

Tiivistelmä - Referat - Abstract
Koulujen oppimisympäristöt muuttuvat jatkuvasti oppijalähtöisemmiksi, mikä vaikuttaa sekä oppilaiden että opettajien rooleihin. Tällä hetkellä tiedetään vähän, kuinka opettajat tukevat oppilaita uusissa, oppilaslähtöisissä oppimisympäristöissä. Tämän tutkielman tavoite on analysoida opettajien interventioita oppilaiden yhteiseen työskentelyyn uudessa, digitaalisessa maker-oppimisympäristössä. Tutkielmassa tarkasteltiin, missä tilanteissa opettajan tekivät intervention oppilaiden yhteiseen työskentelyyn. Sitten analysoitiin, mitä interventiostrategioita opettajat käyttivät tehdessään intervention. Aiemmat tutkimukset osoittavat, että opettajainterventiot voivat tukea yhteistoiminnallista ongelmanratkaisua ja kehittää oppilaiden ajattelutaitoja (Hofmann & Mercer, 2016; Ding, Li, Piccolo & Kulm, 2007). Maker-pedagogiikka taas edistää oppilaiden luovia ongelmanratkaisutaitoja (Bevan et al., 2016) ja mahdollistaa jaetun asiantuntijuuden kehittymisen. (Stevens et al., 2016).

Aineisto kerättiin videoimalla tutkittavan koulun oppitunteja syksyllä 2016. Koulu oli juuri ottanut käyttöön uuden digitaalisen maker-oppimisympäristön (FUSE-Studion). Oppitunneille osallistuivat 9–12-vuotiaat oppilaat. Aineisto koostui 85 tunnista videomateriaalia. Aineiston analysoinnissa käytettiin Jordan ja Hendersonin (1995) interaktioanalyysia. Opettajien käyttämät interventiostrategiat analysoitiin mallintamalla ne Hofmannin ja Mercerin tutkimuksen (2016) mukaisesti.

Tutkimustulokset osoittavat, että opettajainterventioita oppilaiden yhteiseen työskentelyyn esiintyi monissa eri tilanteissa. Yhteensä 55 interventioepisodia luokiteltiin viiteen kategoriaan: (1) haastetehtäviin liittyvät, (2) kurinpidolliset, (3) työskentelyvälineisiin liittyvät, (4) teknologiaan liittyvät ja (5) motivaatioon liittyvät interventiot. Interventioita aloittivat sekä opettajat että oppilaat. Haastetehtäviin, työskentelyvälineisiin ja teknologiaan liittyvät interventiot olivat enimmäkseen oppilaiden aloittamia, kurinpidolliset taas enimmäkseen opettajien aloittamia. Kaikki motivaatioon liittyvät interventiot olivat opettajien aloittamia. Kahdeksaa interventioepisodia analysoitiin tarkemmin, jotta pystyttiin tarkastelemaan opettajien käyttämiä interventiostrategioita. Strategiat muodostettiin Hofmann ja Mercerin (2016) tutkimuksen pohjalta seuraavasti: (1) auktoritatiiviset, (2) aloitteelliset ja (3) jatkuvaan vuorovaikutukseen pyrkivät strategiat. Kaikista kolmesta strategiasta löydettiin esimerkkejä, mutta mikään interventioepisodeista ei täyttänyt tunnusmerkkejä yksinomaan jatkuvaan vuorovaikutukseen pyrkivästä strategiasta. Auktoritatiiviset strategiat olivat yleisiä kurinpidollisissa interventioissa sekä silloin, kun oppilaita ohjeistettiin uuden tehtävän tekemisessä alusta loppuun. Aloitteelliset strategiat, joita jatkuvaan vuorovaikutukseen pyrkivät strategiat tukivat, vaikuttivat edistävän oppilaiden välistä yhteistyötä ja yhteistoiminnallista ongelmanratkaisua.

Opettajainterventiot vaikuttavat olevan tehokas tapa tukea oppilaiden keskinäistä ja jaettua asiantuntijuutta uusissa, digitaalisissa oppilaslähtöisissä oppimisympäristöissä, kunhan opettaja käyttää sopivia interventiostrategioita oppimisympäristön tavoitteiden mukaisesti.

Avainsanat – Nyckelord
Opettajainterventiot, interventiostrategiat, maker-pedagogiikka, digitaaliset oppimisympäristöt, yhteinen ongelmanratkaisu, jaettu asiantuntijuus

Keywords
Teacher interventions, intervention strategies, maker education, digital design and making environments, joint problem-solving, relative expertise

Säilytyspaikka - Förvaringsställe - Where deposited
Helsingin yliopiston kirjasto – Helda / E-thesis (opinnäytteet) *ethesis.helsinki.fi*

Table of Contents

TABLES

FIGURES

1 Introduction

The world of education and schooling is under a constant pressure to change in order to address the global 21st century learning requirements. New learning environments, such as makerspaces that provide possibilities for creative production and learning, are being developed to provide schools and teachers new ways to educate (Blikstein 2013; Kumpulainen 2017; Ramey, 2017; Sheridan et al., 2014). But what does this entail for teachers, and how are they able to keep up with all the new learning environments and programs and change their teaching approach accordingly?

The FUSE Studio, the context of this research, is a novel educational design and making environment that was originally developed in the School of Education and Social Policy at Northwestern University. It is designed to promote students' interest-driven, student-centered, empowering, collective and inclusive learning in STEAM subjects (Science, Technology, Engineering, Arts and Mathematics) by engaging students in different challenges that include robotics, game design, electronics and graphic design (Stevens & Jona, 2017b; Stevens et al., 2016). The FUSE Studio program reflects the goals of the new Finnish National Core Curriculum for Basic Education (NCC, 2014) and by the spring of 2018, it has been implemented into four elementary and two comprehensive schools in the Helsinki area in Finland, one of which is the research site of this study.

According to FUSE developers Stevens and Jona (2017b), teachers need to take a new role within FUSE that is to facilitate the student's activity instead of instructing them. Changing from the traditional role of the teacher, typically characterized by transmission of knowledge and controlling students' activities (Grasha, 1994), to becoming a facilitator of student-driven engagement and learning, is not easy or straightforward. One of the objectives of FUSE is to recognize and advance relative expertise that refers to students developing "expertise relative to each other" through participation patterns (Stevens et al., 2016,

1025). In addition, FUSE aims to expand our understanding of how students' relative expertise grows and how it leads to peer collaboration and sharing (Champion, Penney & Stevens, 2016).

Recent research suggests that students' motives in the FUSE Studio are occasionally challenged by the personal, relational, and institutional demands thus creating tensions between the motives and demands, and altering the social context of students' learning (Kumpulainen, Kajamaa, Rajala, forthcoming). Therefore, new research knowledge is needed on the teacher's role in local school contexts implementing the new curriculum and exploring with new learning environments. Furthermore, it is also important to conduct further studies on tensions these developments entail to the teachers and their relations with students, as to foresight and overcome potential challenges.

This study focuses on the important and yet under-researched topic of teacher's role in student-driven STEAM learning. In specific, the nature of teacher interventions will be investigated, as they facilitate students' joint work and learning in peer groups who are working on FUSE challenges. By researching teachers' intervention strategies in students' joint work in the context of the FUSE Studio and its challenges that aim to promote STEAM learning, we will achieve much needed research-based knowledge on what it entails from the teacher to facilitate and further students' engagement and how to develop students' relative expertise in interest-driven peer collaboration and learning.

2 Maker education

In this chapter, maker education and makerspaces will be presented since the FUSE Studio, the context of this research, follows many of the principles of maker education. Special focus will be given to an educator's role in maker education before moving on to introducing the FUSE Studio as a digital design and making environment, focusing again to a teacher's role in FUSE.

2.1 Maker education and makerspaces

Makerspaces are connected to the maker movement that refers to people working creatively to produce daily artifacts and then share their products with others both in physical and digital forums (Halverson & Sheridan, 2014). Educational makerspaces are thus ideal learning environments for maker education (Kurti, Kurti & Fleming, 2014). Makerspaces can be defined as "informal sites for creative production in art, science, and engineering where people of all ages blend digital and physical technologies to explore ideas, learn technical skills, and create new products" (Sheridan et al., 2014, 505).

Maker education stems historically from constructivist philosophy (Kurti, Kurti & Fleming, 2014). The philosophical base of constructivism is extensive but Savery and Duffy (1995) recapitulate its three main notions. The core concept of constructivism is that what is learned cannot be separated from how it is learned since same understanding can be reached by a variety of experiences. Secondly, all learning environments should have a stimulus for learning, most often a cognitive conflict that determines the learner's intellectual and pragmatic goals. Finally, social environment is crucial in order to knowledge to develop at an individual's level (Savery & Duffy, 1995). The maker education, in turn, builds on the basis of constructionism which applies the ideas of constructivist learning and its philosophy of hands-on learning (Kurti, Kurti & Fleming, 2014).

It has been argued that the maker movement is closely connected to the earlier hacker movement since they have similar methods towards working and learning that include identities (hacker, maker) and spaces (hackerspace, makerspace) (Marusteru, 2017). However, maker culture can be seen as more creative since it does not aspire to create a specific set of skills but rather to provide

the right materials and resources that anyone could use to create and make (Marusteru, 2017). Even though making activities can support creating different artifacts by benefitting from technologies, these activities promote emotional, relational and cultural processes as well (Kumpulainen, 2017, 14).

Making is based on students' own interests and ideas (Bevan et al., 2016). It aims to promote students' creative problem-solving abilities, builds their agency, persistence, and self-efficacy, as well as helps to deepen students' understanding and ideas (Bevan et al., 2016). In addition to this, making can be seen as advancing inquiry-based practices as well as entrepreneurship for students (Bevan, Gutwill, Petrich & Wilkinson, 2014). A study by Bevan and others (2014) focused on tinkering, which is a form of making that emphasizes improvisational problem solving. In their Tinkering studio, they identified four different dimensions that tinkering supports: engagement, initiative and intentionality, social scaffolding, and development of understanding (Bevan et al., 2014).

Some researchers criticize maker education by claiming that similar ideas have existed for decades. They compare it to for instance John Dewey's ideas of learning by doing. Indeed, maker education shares some of the ideas of learner-driven experiments that should be connected back to real-world contexts (Bevey et al., 2014, 3; Blikstein, 2013, 4; Ramey, 2017, 19). However, like other theories over the past century, maker education can be seen as developing the ideas of learning by doing further and combining them with STEM education as well as arts and creativity.

STEAM education refers to science, technology, engineering, arts, and mathematics. It has previously been referred to as STEM education but arts were later added to emphasize the creative subjects. Both terms are still being used both in research and in the world of education. Lately nations have begun to worry that STEM education in schools is not sufficient. Especially in the United States, many assessments show that students are not reaching the necessary levels of skills in math and science (Kuenzi, 2008). Hence, creative learning environments have been created to support STEM education and emphasize arts as a part of it. Maker education provides ways to benefit from digital technologies to reach the institutional objectives for STEM learning (Halverson & Sheridan, 2014). Moreover, through combining STEM with art education, students can gain new

understanding and create artifacts that go beyond discipline barriers (Peppler & Wohlwend, 2018). Although making is often connected to STEAM education, it remains interdisciplinary and is essentially driven by students' interests (Kumpulainen, Kajamaa & Rajala, forthcoming).

2.2 Educator's role in maker education

Maker education differs from traditional school education in many ways. In order to successfully institutionalize making, the essence of the movement and its democratizing potential has to be kept (Halverson & Sheridan, 2014). Thus, when implementing makerspaces into schools, an educator's role is both affected and crucial in building a makerspace. Researchers have previously observed that changing teachers' perceptions towards students' self-regulated learning as a part of educational reforms is challenging and can even make teachers adhere to subject-matter-oriented methods (Meirink, Meijer, Verloop & Bergen, 2009, 90). Changing of existing teaching practices is also difficult, especially when moving from teacher-centered methods to student-centered processes (Grasha, 1994, 145). In order to change teachers' perceptions, research is required to determine what possible preconceptions teacher may have regarding novel learning environments such as makespaces. After acknowledging possible conceptions, research can be conducted to determine whether these conceptions are visible in teachers' work. For example, whether the teaching strategies they use are consistent with their preconceptions.

Cohen, Jones & Smith (2018) researched preservice and early career teachers' pre- and misconceptions about maker education. Two main misconceptions emerged. First, teachers felt that making activities could only be utilized in reaching a narrow, content-based learning goal such as teaching about force in physics or about shapes in geometry. Secondly, they felt that technology or certain tools are essential to making activities for example they might regard a 3D printer as a compulsory resource. Acknowledging of such preconceptions is important so actions can be taken before teachers adopt a negative attitude towards integrating making into their classrooms (Cohen, Jones & Smith, 2018). Peppler and Wohlwend (2018, 97) suggest a possible course of action where early career teachers are provided with field experiences to implement transformative STEAM

education. With additional guidance, teachers can be taught to see the potential of innovative making practices. Since creative STEAM approaches have a positive effect on students' learning and participation, early career teachers should be better trained and engaged in such approaches and their possibilities (Peppler & Wohlwend, 2018).

Teacher's role in maker education should be compared to their customary role in group work rather than in lecture-type teaching in classrooms. Earlier research highlights teacher's role in group work as a classroom manager (Ding et al., 2007). In maker education, teacher's role should be more of a facilitator of learning processes (Blikstein, 2013, 5). This includes facilitating both the student's individual learning as well as collaborative processes in a group.

Tran (2011) claims that teachers need to have an understanding of out-of-school learning in order to aid students in making connections between in-school and out-of-school science experiences. Relating this to maker education means that teachers need to be able to connect the learning experiences both to a theoretical base as well as to concrete examples. Sheridan and others (2014) illustrate this by pointing out that teachers might usually use hands-on activities to teach about circuits in electricity. In makerspaces, this knowledge about circuitry is "*used* to make a night-light, customize a bike, fix a game controller, and photograph the Earth from space" (Sheridan et al., 2014, 528, emphasis in original).

2.3 The FUSE Studio as a digital design and making environment

The FUSE Studio is a novel digital design and making environment that engages students in science, technology, engineering, arts and design, and mathematics (STEAM) topics (Penney, 2016; Ramey, 2017; Stevens & Jona, 2017b). The FUSE Studio program was developed in the School of Education and Social Policy at Northwestern University in Chicago, the United States. As a learning environment, FUSE is designed to be interest-driven, learner-centered, and inclusive. According to Stevens and others (2016), FUSE empowers learners by allowing them to choose the challenges they wish to work on. It also enables students to work together and develop each other's relative expertise (Champion, Penney & Stevens, 2016, 1028).

2.3.1 The research base of the FUSE Studio

Jaakko Hilppö (personal communication, November 30, 2016) recapitulates the history of the FUSE Studio. Originally, the first challenges were tested in libraries, summer camps and after school clubs around the Chicago metropolitan area. FUSE was initially designed for that type of settings since it was assumed that the pedagogical goals would be best achieved in less structured learning environments. Gradually FUSE expanded to some of the schools in the area. FUSE's spread is similar to the general maker movement, which originally emerged from independent organizations and then spread to museums, libraries, schools, community colleges, home schooling groups, after school clubs, and institutions of higher education (Halverson & Sheridan, 2014).

Hilppö (personal communication, November 30, 2016) continues that in 2013 the near-by school district became more interested in FUSE and wanted it to be a part of their official science curriculum, and not only an after school activity. Slowly FUSE started to spread to different schools within that particular school district. By 2016, 4000 students in 27 schools within that district participated in FUSE as a part of their STEAM education. Gradually, FUSE started to spread out to other states and internationally. According to the FUSE website, currently over 130 schools and organizations are using the program and yearly it reaches 16,000 students internationally. In Finland, FUSE has been implemented into four primary schools and two comprehensive schools in Helsinki. It is also being used in the Finnish Science Centre Heureka.

According to Reed Stevens and Kemi Jona (2017a), the main developers of FUSE, three main lines of research have affected the conceptual framework of the FUSE Studio program. Firstly, they wanted to invent an alternative way for students to participate in STEM (science, technology, engineering, and mathematics) learning. This abbreviation was later expanded to include arts and design as a part of the mathematics and science program, which is why it is now referred to as STEAM learning. Based on the developers' previous findings, they felt that opportunities for STEM learning were often defined too narrowly in schools. They wanted to support the students' ideas and interests and guide them

towards active, social participation that could result in relative expertise (Stevens & Jona, 2017a).

Secondly, Stevens and Jona (2017a) emphasize connected, peer-based learning. The idea comes from the Digital Youth Project (Ito et al., 2009) where it was researched how youth both socialize and learn through new media forms and what this implies for educators and the new role of education. Ito and others (2009) identify three genres of participation: hanging out, messing around, and geeking out. The three genres describe the social dynamics of media engagement. Hanging out is more friendship-centered, messing around focuses on improving youth's understanding of technology and media, and geeking out represents autonomous and interest-driven engagement with technology (Ito et al., 2009). While the Digital Youth Project aimed at connected learning with various forms of digital media, FUSE pursues to facilitate similar results in the area of STEM learning (Stevens & Jona, 2017a).

Finally, the research base of FUSE benefits from video game design principles. The program is not a video game itself but it conceptualizes participation structures from video games in order to benefit from them in STEM learning (Stevens & Jona, 2017a). While playing video games, players tend to do it voluntarily, they are engaged and persistent even with harder challenges that require long-lasting efforts. In addition to that, players usually develop their skills through hours of practice and are able to apply what they have learned both within a level and across levels in order to "level up" (Gee, 2007). These were the main features Stevens and Jona wanted to transfer to FUSE. In his previous research, Stevens also discovered that when young people face challenges in video games, they work with each other in real life as well. They create a variety of 'learning arrangements', which means that they co-operate in order to find new and creative ways of solving the problems in hand. Both the main principles of video games as well as the social aspect of learning together are combined in FUSE's basic philosophy. The idea is to create a physical and digital space that enables students to create new learning arrangements (Stevens & Jona, 2017a).

According to the Finnish National Core Curriculum, a learning environment should be pedagogically versatile, adaptable and it should support interaction, participation and collaborative constructivist learning (NCC, 2014). The learning

environment created in FUSE can be seen as one that meets these general goals set for learning environments.

The current government programme in Finland includes a ‘knowledge and education’ section that has six key projects. The first one is aimed specifically at comprehensive schools. The goal is to develop new learning environments and digital materials by introducing new digital environments that allow a variety of different learning styles. The overall aim of this project is to improve learning outcomes and reduce differences between the outcomes of different students (Government Publications, 2015). A similar goal can be found in the national curriculum (2014) where it is stated that information and communications technology (ICT) is a crucial part of varied learning environments. New solutions concerning ICT are utilized in schools in order to support and advance learning (NCC, 2014). The research project concerning the FUSE Studio aims to provide information and new solutions that benefit the advancement of the government’s key projects and the new curriculum.

2.3.2 Teacher’s role in the FUSE Studio

Customarily it is thought that authentic makerspaces cannot exist in schools since as a formal environment it creates disciplinary standards for curriculums and assessments (Sheridan et al., 2014, 527). Hence, the FUSE Studio is defined as an alternative infrastructure for learning (Stevens et al., 2016) so not precisely a makerspace. It differs from free makerspaces since most FUSE studios are in-school and lessons occur as a part of a regular school day (Ramey, 2017, 42). One of the original ideas of the FUSE Studio program was to create empowering learning arrangements that would not cause chaos what teachers may fear when removing traditional classroom structures (Penney, Jona & Stevens, 2016). The developers of FUSE believe that it does not lead to a chaotic atmosphere in classrooms but rather enables students to take responsibility for their learning by self-directing their work and staying productive (Penney, Jona & Stevens, 2016, 1027). FUSE can be seen as slightly more structured than free makerspaces. However, Ramey (2017) claims that FUSE meets the requirements presented in Sheridan and others’ definition (see p. 9) of a makerspace. Thus, its roots are

firmly in maker education and it follows many of its principles so understanding of makerspaces and teacher's role in them is crucial for this research.

Implementing the FUSE Studio into a school requires a teacher to acquire a new kind of an approach to teaching if compared to a traditional classroom. For instance in FUSE, Penney (2016) states that teachers should not mediate all of the learning arrangements. On the contrary, they should hand over a part of their control to the students, who can then take responsibility over their own learning, the materials, chosen workspace and social interactions with others (Penney, 2016, 4). While teachers share some of this responsibility, students' work can be interest-driven which enables them to shape their own learning (Ramey, 2017, 207). FUSE provides opportunities to support student agency in a way that leads to students creating new learning opportunities within their own STEM interests (Hilppö, Stevens, Jona, Echevarria & Penney, 2016). These opportunities may be unintended by the developers and teachers but anticipated by the pedagogical program design (Hilppö et al., 2016). However, it is uncertain whether teachers would accept students extending the learning activities or guide them back to the original challenges. This is one of the reasons why the role of the teacher in FUSE needs to be investigated further.

In FUSE, teachers or other adults are not able to be experts in all the different technology that is used, which results in them maintaining a novice position alongside their students (Penney, 2016). Thus, the traditional expert teaching style, where a teacher transmits detailed knowledge to students, has to make way to a facilitating teaching style (Grasha, 1994). As a facilitator, a teacher emphasizes students' responsibility as a learner through teacher-student interactions of asking questions and offering alternatives (Grasha, 1994). Therefore, teachers should not be able to give direct answers but rather work together with the students by asking the right questions and engaging in collaborative problem solving (Penney, 2016, 22). This is typical to all making activities. While students can use technology and build their projects, teachers facilitate these processes (Blikstein, 2013).

One of the goals of FUSE is to develop a way to support relative expertise (Champion, Penney & Stevens, 2016; Penney, 2016). Relative expertise refers

to students developing “expertise relative to each other through individual patterns of participation” and thus relying on peer expertise in the different challenges (Stevens et al., 2016, 1025). In addition to students helping each other, students can demonstrate their relative expertise by helping teachers as well. For example, a student may be able to guide a substitute teacher in using a 3D printer (Ramey, 2017, 95–96) or start giving 3D printer tutorials to teachers and other school staff (Champion, Penney & Stevens, 2016, 1028). In FUSE, both teachers and peers can recognize students as relative experts and thus identify them as learning resources (Champion, Penney & Stevens, 2016, 1028).

When comparing this study on teacher interventions in the FUSE studio to Hofmann and Mercer’s research on teacher interventions, some differences should be noted. For example, unlike this research on the FUSE Studio, Hofmann and Mercer’s (2016) study focused solely on mathematics and science lessons. Those lessons were also held in students’ usual classrooms (Hofmann & Mercer, 2016). The researched school of this study had a separate computer classroom for FUSE so the students were not necessarily used to working in that specific learning environment. In addition, Hofmann and Mercer’s study (2016) only accounted for teacher interventions in fixed groups that were initiated by a teacher. This research included both teacher and student initiated interventions that were aimed at joint work but not necessarily only in fixed student groups.

Some research has already been conducted on FUSE Studio and its learning possibilities (see Penney 2016; Ramey 2017). However, the role of the teacher in the novel learning environment has not been studied. This research aims to provide examples of what kind of a role a teacher has in FUSE, in which situations teacher interventions are made in students’ joint work and which intervention strategies teachers use. Not only does this research benefit future implementations of this learning environment but it also contributes to the idea of what it is like to be a teacher in 21st century education.

3 Promoting students' joint work via teacher interventions

In this chapter, previous research concerning teacher interventions on students' small group work will be introduced. Review of existing research will focus on teacher interventions in students' joint work especially in science classrooms. Student initiated interventions and intervention strategies will be presented subsequently.

3.1 Teacher interventions

According to Johnson & Johnson (2002) a teacher intervention is one way of monitoring students' learning. However, a teacher should not intervene excessively since monitoring can also be done without intervening (Chiu, 2004). At best, a teacher intervention is a resource of teaching that can be aimed at improving students' thinking skills (Ding, Li, Piccolo & Kulm, 2007). However, an intervention's effectiveness depends on the intervention strategy as well as length and frequency of interventions. An effective teacher intervention aims to help students either to complete the task or to work collaboratively (Johnson & Johnson, 2002). In this study, a teacher intervention refers to a situation where a teacher intervenes in student's joint work for a varied period of time, and for various number of reasons that are later categorized.

Interventions in students' small group work and student-teacher interactions have been researched especially widely in mathematics and science classrooms (see Chiu, 2004; Cobb, Wood & Yackel, 1991; Ding et al. (2007); Dekker & Elshout-Mohr, 2004; Hofmann & Mercer, 2016). Brodie (2000, 9) suggests that teacher interventions in mathematics can be seen as crucial since students may reinforce each other's misconceptions rather than defy them. Ding and others (2007) agree on the importance of teacher interventions, especially in group work where students are more likely to give up if help is not provided when necessary.

Hofmann and Mercer (2016) researched teacher interventions in small group work in secondary mathematics and science lessons. The study focused on how teachers can most effectively intervene in collaborative problem solving i.e. a pair or a group of students that encounter a problem (Hofmann & Mercer,

2016). They discovered different characteristics that teachers used in their interactions with students and categorized them into three different intervention strategies (see 3.3). These intervention strategies of this study are modelled after Hofmann and Mercer's research (2016).

Dekker and Elshout-Mohr (2004) examined in their study how students' results in a mathematics test differed depending on whether the teacher's help they received was a product-help condition or a process-help condition. Product-help was mainly supportive and included regular activities from their own teacher for example giving hints and asking students to explain their answers. Whereas process-help aimed to promote the interaction process and collaborative work instead of the problem-solving process. The results indicated that process-help improved students' mathematical level more than product-help and supported the convergence of students' scores (Dekker & Elshout-Mohr, 2004).

Ding and others (2007) researched how the teacher intervention's frequency, length, and choices influence the quality of the intervention. They discovered that the intervention length depends on the group situation but both too quick and too prolonged interventions affect learning negatively. Similarly, the frequency of intervention depends on the group's needs. If the teacher's visits are too infrequent, the group may be driven off-task due to simply not understanding the task or directions (Ding et al., 2007). Other studies have also demonstrated that students tend to be more on-task and develop more ideas after talking to a teacher (Chiu, 2004). Finally, Ding and others (2007) discovered that the quality of intervention was dependent on the way teachers supported students' mathematical thinking. Instead of immediate answers, teachers should analyze the possible cognitive obstacles in students' thinking and then aim to deepen their thinking (Ding et al., 2007).

It should also be noted that the presented studies focused on teacher interventions in collaborative learning. In addition, a few of these studies focused specifically on cooperative learning, which is a method of learning that requires structured cooperative efforts from the teacher (Johnson & Johnson, 2002). This study uses the term joint work to refer to students working together, either in pairs working side by side on an individual or shared challenge or in groups working

collaboratively. Since a teacher can choose to intervene with an individual student, small group, or whole class, the challenges of interventions change accordingly (Ding et al., 2007). Different kind of interventions strategies may be used when supporting the learning of students working by themselves. When intervening in small groups, teachers need to pay special attention to how an individual student's thinking and comprehension of the subject matter is formed (Ding et al., 2007). The goal is that all students form an understanding of the solution process.

Research on teacher interventions in general aims to determine and describe effective ways for teachers to intervene in students' collaborative work. While group work and striving towards pupil participation is becoming more universal, it should not be done for arbitrary reasons (Galton & Hargreaves, 2009). Research is required to determine when and what kind of teacher interventions are required to support students' collaborative work and peer learning.

3.2 Student initiated interventions

Most of the teacher intervention studies focus on interventions initiated by a teacher. However, a teacher intervention can also be initiated by a student seeking help. The reasons and results of help-seeking in the classroom have been researched widely. The critical stage in help-seeking is the moment between a student realizing they need help and the decision on whether they are going to seek help (Ryan, Pintrich & Midgley, 2001). In a novel learning environment, it is crucial to determine whether students identify their difficulties and seek help in addition to teacher initiated interventions.

Extensive research has also been conducted in order to determine why some students clearly avoid seeking help in the classroom (see Ryan, Pintrich and Midgley, 2001). Some reasons include that it is not practical to ask for help under certain circumstances, there may be norms that prohibit help-seeking or the student may feel that it is not effective to seek help, either time-wise or expertise wise (Ryan, Pintrich & Midgley, 2001). Psychological reasons are separate from previous practical reasons. Thus, it is important that while a teacher carries out group work, the participation structures and interaction processes are examined (Kovalainen & Kumpulainen, 2005). Previous research indicates that stu-

dents that do not seek help tend to stay off-task or try various unproductive methods in vain (Chiu, 2004). One typical reason for failing group efforts is that a teacher has not provided help when necessary (Ding et al., 2007).

Often a student group might ask for help when they cannot reach consensus or when none of its members know how to proceed. Teachers should spend more time with these groups in order to keep the students on task-related thinking (Ding et al., 2007). A teacher can neither rely on any of the group members to seek help in a plight, therefore a teacher needs to be able to determine when to intervene (Chiu, 2004). In situations where the group cannot move forward, a teacher may easily resort to authoritative methods such as immediate answers. Instead, peer resources and collaboration should be encouraged so students can share ideas and expand their thinking (Ding et al., 2007).

One of the basic elements of cooperation is group processing that needs to include both teacher and student processing in order to result in successful problem solving (Johnson & Johnson, 2002, 97–98). This applies to teacher interventions as well, since effective intervening should combine both teacher and peer resources (Ding et al., 2007). Ideally, in addition to supporting interactions and group processing, a teacher could teach students the necessary tools they need to think critically and develop their problem-solving skills rather than just producing the correct answer (Hofmann & Mercer, 2016). By appreciating and considering students' ideas as feasible, students are more likely to stay on-task and develop their ideas as well as their autonomy (Chiu, 2004). In addition to combining teacher and peer resources, an effective teacher intervention strategy modifies the instruction based on the students' needs and focuses both on cognitive and metacognitive aspects (Ding et al., 2007). Next chapter will present three different kind of intervention strategies that teachers have been identified to use when intervening in students' joint work.

3.3 Intervention strategies

Intervention strategies refer to the turn-by-turn interactions teachers use when intervening in students' work and the communicative consequences that follow the teacher intervention (Hofmann & Mercer, 2016, 404). Hofmann and Mercer (2016) categorized three different strategies depending on the type of interaction

and advice the teacher gave the students: (1) authoritative strategies, (2) initiating strategies and (3) continuing interactive strategies. In addition to the intervention strategy, the length and frequency of interventions affect the quality of an intervention (Ding et al., 2007).

Authoritative strategies refer to a teacher taking the lead in finding a solution to a problem. This could mean that the teacher is guiding students towards a resolution step-by-step without stopping to make sure what the students understand. In addition, the teacher might accept a correct answer from a student without asking for an explanation or further clarification (Hofmann & Mercer, 2016). Hofmann and Mercer (2016) present the following example where a teacher joins a group and asks for the correct answer. Two students give different answers and the teacher ignores the incorrect answer and acknowledges the correct answer without probing for further understanding of the matter. The teacher does not advice or explain the answer to those two students who answered incorrectly. Authoritative strategies also include high teacher dependence in the solution process. The process is often aimed at finding the right answer rather than encouraging students to think actively about the problem (Hofmann & Mercer, 2016).

Initiating strategies mean that a teacher does not take a leading position in attempting to find a solution. Instead, they use strategies that initiate interactions within the group. Hofmann and Mercer (2016) defined the following opening strategies as initiating: (1) inviting students to speak, (2) listening silently to the discussion, (3) making reference to the ‘ground rules’ of the activity; and (4) focusing students on task. Teachers could use one or more of the opening strategies in order to be categorized as using an initiative strategy. In an example from Hofmann and Mercer’s study, a teacher intervenes in a group’s work and encourages students to share their ideas, listens to them and repeats their answers without necessarily revealing whether the answer is correct or not. In another example, the students are not contributing to group work since they do not know what to do. The teacher intervenes, refocuses the students on task, and encourages suitable interactions that would help the group in solving the problem (Hofmann & Mercer, 2016).

Continuing interactive strategies refer to situations where teachers keep encouraging students’ discussions and do not intend to end the conversation.

According to Hofmann and Mercer (2016), these strategies may include: (1) repeating relevant ideas expressed by students, (2) probing and exploring students' understandings, (3) encouraging students to compare and test ideas; and (4) identifying resources for thinking. Examples of these strategies could be seen in multiple cases in Hofmann and Mercer's study (2016) where teachers would ask students to repeat other group member's answer, repeat their own answers in different words or to ask students to compare their perspectives and comment on each other's ideas. A teacher might also provide added information or resources to aid the solution process for instance when a teacher referred the students to mathematical table.

4 Research tasks and research questions

The aim of this study is to analyze teacher interventions in students' joint work in a novel design and making environment. First, the study aims to categorize the types of situations where teachers intervene in students' joint work. Subsequently, it analyzes further which intervention strategies the teachers use when intervening.

The research questions for this study are the following:

1. In which kind of situations do teachers intervene in students' joint work in the FUSE Studio?
2. Which intervention strategies do the teachers use when intervening in students' joint work?

The research questions were answered by using a qualitative approach of interaction analysis. The data consisted of video material that was filmed at the research site during the participating school's FUSE Studio lessons.

5 Research site

This chapter will introduce the school, which is the research site where the video data were collected. General information about the school and its curriculum will be presented first before explaining how the FUSE Studio was implemented in the school.

5.1 The school in focus

The researched school, where the data were collected, is a city-run comprehensive school providing both primary and secondary level education. The primary school consists of grade levels one through six where students are between 6–12 years of age. The school has 535 students (279 boys and 256 girls) and 28 teachers in total. Out of the students, 8% speak something other than Finnish as their first language. In addition to Finnish, the most common first languages are Somali, Estonian, Russian, and Arabic. Families living in the area have different educational backgrounds, highest level of education being the following: comprehensive school 24%, vocational school 35%, and higher education 41% (Helsinki by District 2015).

The city of Helsinki has started an extensive program for digitalization in teaching that runs from 2016 to 2019. In this program, 60 schools are experimenting how digitalization can be used to improve teaching and learning. Out of the 60 schools, 49 are comprehensive schools, 10 high schools, and 1 vocational school. The program consists of five different themes from which the researched school belongs to the theme “school without text books” (The City of Helsinki, 2016).

The researched school’s curriculum has an overall emphasis on design learning which supports creative problem-solving skills that benefit the student

beyond individual subjects (local curriculum document, 2016[1]). The objective is to make learning innovative, learner-centered and to follow the guidelines of progressive inquiry (local curriculum document, 2016[2]).The FUSE Studio as an optional subject is one of the ways the school anticipates meeting these goals. The school's optional subjects aim to expand students' competence according to their individual choices. In the school's list of optional subjects, FUSE is listed as one connecting to artistic and practical subjects (local curriculum document, 2016[3]). This derives from the national curriculum (NCC, 2014), where it is stated that each school has to offer optional lessons to support artistic and practical subjects (including music, visual arts, crafts, physical education, and home economics).

The FUSE Studio lessons were held for 9 to 12-year-old students. In the fall of 2016 three different groups started FUSE lessons, one group from each grade level (4th to 6th grade). In the beginning of the fall each grade level had one 45-minute lesson a week. Later in the fall, each lesson was extended to 60 minutes so the students could better concentrate on their work without interruptions. There were 32 students (22 boys and 10 girls) in the 4th grade group, 30 students (19 boys and 11 girls) in the 5th grade group, and 32 students (19 boys and 13 girls) in the 6th grade group. Each group was assigned a teacher in charge but other teachers and teaching assistants worked in the groups as well. The school had added staff resources throughout the fall to make the implementation of FUSE as fluent as possible. The teachers had participated in a 2-day FUSE training in the spring of 2016, which was held by the members of the FUSE team from the United States. The teachers were presented the opportunity to partake in the training according to their own interests in the field of innovative STEAM learning.

The school had six male and two female teachers who taught the FUSE lessons. This study features examples of four male (John, Greg, Bill and Sam) and one female (Beth) teacher. John was a primary school teacher who had temporary post at the school. The following fall (2017), he was appointed to a post at

---

[1] The text refers to the researched school's curriculum.The name of the school has been anonymized.
[2] The name of the school has been anonymized.
[3] The name of the school has been anonymized.

the school. Greg was a secondary school crafts teacher (hard materials) who was in charge of the FUSE team of teachers. Outside of work, he was also involved in teaching at a children's electronic art school. Bill was a primary school teacher who also taught crafts (hard materials). Sam was a crafts teacher (hard materials). Beth was a primary school teacher. Bill, Sam, and Beth all had temporary posts and changed schools the following fall (2017).

The researched school's curriculum emphasizes thinking skills and other skills that teach students how to learn (local curriculum document, 2016[4]). These skills are also an important part of the national curriculum reform. They can be supported by creating learning environments that utilize games, playing, physical activities, experimenting, and learning by doing (NCC, 2014). FUSE can be seen as one example of such a learning environment.

The Finnish National Agency of Education (FNAE) published a new National Core Curriculum in 2014 (NCC, 2014). The national curriculum works as a foundation for municipalities who have to prepare their own local curricula. Both the local and each school's individual curriculum are based on the national framework but they give more detailed instructions for school work and take local needs into consideration (FNAE, 2014). Schools had to implement the new curricula at the beginning of the school year in the fall of 2016. Some schools and teachers experienced difficulties implementing the new curricula and meeting its learning requirements without proper schooling or new learning materials. Hence, some schools decided to participate in programs such as the digitalization project of which the FUSE Studio is an example.

The FUSE Studio consists of 29 different STEAM-challenges (see Appendix 1) that level up like video games. By each level, the challenges get harder and require the student to build on previous knowledge. The number of levels in each challenge vary from 2 (e.g. in *Spaghetti Structures*) to 8 (in *Robot Obstacle Course*). Once a student has completed a level, they can move on to the next one by documenting their completion of the previous challenge. This can be done by uploading digital evidence e.g. photos or video to the student's individual

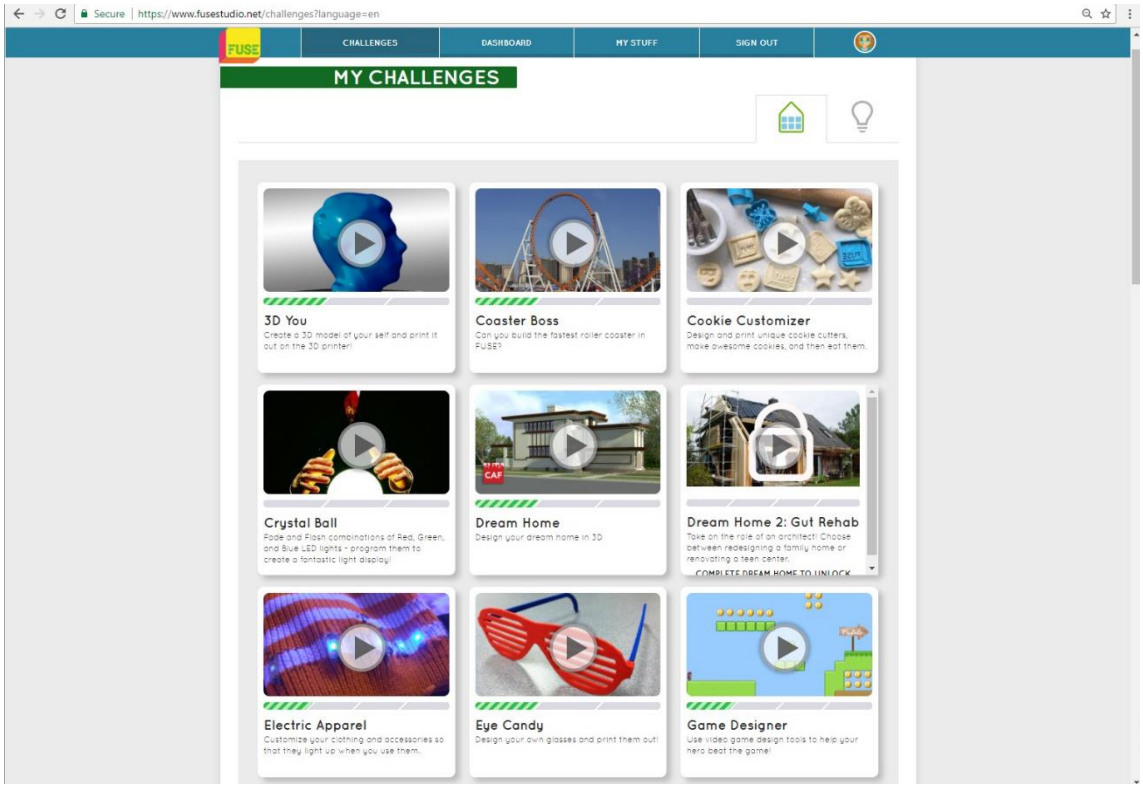
[4] The name of the school has been anonymized.

FUSE website (Stevens et al., 2016). At the time of data collection in fall 2016, the researched school had 14 challenges out of 24 to work on (five challenges have later been added to FUSE). When signing in to the FUSE Studio, the student sees all the challenges they have started (see Picture 1).

Teachers could open and close the FUSE challenges depending on which tools and equipment were available. For example, the *Spaghetti Structures* challenge might run out of spaghetti or marshmallows that the staff was required to fill. A teacher could also regulate the open challenges by determining which skills students needed to be working on. Out of the 29 challenges, thirteen are performed on a computer, either within the FUSE website or at another website (e.g. *Ring Tones*, which uses the Soundation website) or with additional software (e.g. *Game Designer*, which uses Stencyl software). The required software had been previously installed into the school's computer by the staff. Six of the challenges required a 3D printer, which the researched school was not able to acquire during the fall. Hence, students were unable to finish some of the challenges like *Jewelry Designer* or *Keychain Customizer*, in which the idea is to print out your final product. Especially girls showed interest in these challenges and even started the planning phase of *Jewelry Designer*. Teachers informed the students that they did not know when the school could acquire a functioning 3D-printer but they did not prevent them from working on said challenges nor did they encourage them to change the challenge they were working on.

The students of the researched school could use the school's computer lab, one other classroom, and the corridor during the FUSE lessons. In the computer lab, there were 22 desktop computers and the students could also use separate laptops. Students could freely choose where they wanted to work and whether they wanted to work alone, in pairs or in small groups. The choice often depended on which challenge the student was working with. For example, the *Dream Home* challenge was often an individual one whereas the *Coaster Boss* practically required teamwork. Since they could also choose the challenge they wished to work on, the chosen challenge often guided their choice of location and group size. For example, *Coaster Boss* and *Solar Roller* took up plenty of space so students often worked in the corridor on those challenges. *Dream Home* and *Ringtones* did not require any extra materials or space so students often worked

in the computer lab or on laptops at the separate classroom. If students needed separate materials for the challenge, they would get them independently from the supply cabinets in the computer lab. It was also a student's choice if they wanted to complete all levels in a particular challenge or whether they wanted to try out different challenges completing one level, or none at a time.



Picture 1. "My challenges" view for the student.

6 Methodology

The data of this study were collected by videoing the FUSE Studio lessons at the participating school. In this chapter, the qualitative research strategy of this study will be introduced as well as the key elements that define it a case study. The methods of video data collection at the researched school will be discussed. The data were analyzed by using interaction analysis (Jordan & Henderson, 1995) and the process will be explained below in detail.

6.1 Research strategy and research design

The research strategy of this thesis is qualitative (Miles, Huberman & Saldana, 2014). This research is a case study since it focuses on one particular school's FUSE Studio lessons in the fall of 2016. A classical definition of a case study is "an intensive, holistic description and analysis of a single instance, phenomenon, or social unit" (Merriam, 1988, 21). This definition refers to the product of an investigation. Merriam (1998, 34) has later specified that in addition to the end product, a case study can be defined in the process of implementing the investigation. Hamilton (2012) presents key elements of a case study as a research genre: a bounded unit, located within local communities, involves interactions between the case and the wider world, focus on collecting rich data in order to capture the complexity of a case, data collection over extended periods and spending time with those being researched. All of these were realized in this research. The bounded unit was an institution i.e. a local comprehensive school. The research interacts with Finnish curriculum changes as well as with international makerspace education, especially research concerning the FUSE Studio. The video data were chosen to be able to focus on different aspects of the lessons and it was collected weekly over a period of three months. The researchers collected the data themselves to be able to interact with both the teachers and students.

6.2 Methods of data collection

The methods of data collection in this study were video recordings. The data consisted of 177 video recordings that were filmed from the beginning of September to end of November in the fall of 2016. Three FUSE lessons were filmed each week. The videos were filmed by a research group that included four Master students and three university researchers. All researchers had different research interests but general field notes and observations could be shared among researchers during videoing and afterwards.

The research group had four cameras in total. Depending on how many researchers were available to film the lessons on given days, two to four cameras were filming at once. Generally, half of the cameras were videoing teachers and half focused on students working in the learning environment. Student cameras were fixed to film a single student or group of students, and they were not moved during filming. Teacher cameras were used by researchers who followed the teacher around the classrooms and hallway. Wireless microphones were attached to the video cameras to record the speech of students and teachers. The researchers aimed to include computer screens in the videos, whenever it was deemed as a part of the problem solving or interactions.

Occasionally a video could be cut off during filming, which is why a single lesson may be divided into more than one video clip. All 177 videos clips are listed in Appendix 2, where the cut off clips have been combined into a single video. Video clips varied in length from a few seconds (accidental recordings) to 65 minutes with a total of 75 hours of video material.

6.3 Methods of data analysis

The video data were analyzed by using the techniques of Jordan and Henderson's (1995) interaction analysis as explained below. The video material was approached inductively by first approaching the video corpus as a whole and then focusing on selected events in greater depth (Derry et al., 2010, 9). This can also be referred to as a whole-to-part approach where the focus is on the interaction processes (Erickson, 2006, 183). In addition to the videos' visual data, both verbal activities and material objects were included in the analysis (Jordan & Henderson, 1995).

All the 177 videos were first watched and compiled into a content log that included the following details: date and name of video, length of video, who the camera was filming, which challenge or challenges were worked on, and who was working on a challenge and where (see Appendix 2). This log was done by one of the members of the research group. The analysis for this research started by browsing through the list of videos and their descriptions. First, it was crucial to choose videos or parts of videos that depicted teacher interventions directed at students' joint work i.e. students working in pairs or groups. Finding these events i.e. sections of interactions was the analytic foci through which the videos were watched (Jordan & Henderson, 1995, 57). The videos that had visible teacher interventions in students' joint work were then collected into a separate table of 62 video clips (see Appendix 2, where these videos are marked in bold).

Within the teacher intervention events, it was crucial to identify "smaller units of coherent interaction" (Jordan & Henderson, 1995, 57). These units were named intervention episodes. The intervention episodes were found by using purposeful sampling. Purposeful sampling design refers to the identification and selection of all cases that are information-rich and meet the predetermined criterion of significance (Palinkas et al., 2015). All videos including intervention episodes were viewed but the data were then condensed to include episodes that represented all the different reasons and strategies for interventions. Data condensation is a part of data analysis that aims to make the data stronger by focusing on meaningful data chunks (Miles, Huberman & Saldana, 2014, 12). After condensation, the remaining data were transcribed. The transcriptions included both the talk and nonverbal behavior of participants where necessary (Erickson, 2006, 184). The transcriptions were first done in Finnish and then translated idiomatically into English.

After identifying 55 teacher interventions, the analysis was guided by the first research question. The videos were then viewed with the intent of analyzing the situation where the teacher intervened. The interventions were divided into teacher and student initiated. These intervention episodes were then classified into five categories: (1) STEAM-challenge related, (2) disciplinary, (3) material related, (4) technology related, and (5) motivation related interventions. STEAM-

challenge refers to FUSE challenges that were connected to science, technology, engineering, arts, and mathematics (see 2.3).

The analysis was then continued by viewing the videos again from the viewpoint of the second research question. From the previously analyzed 55 intervention episodes (see Figure 1), eight episodes that included further interactions between students and teachers after the initial intervention were chosen to focus more closely on the intervention strategy. These intervention episodes were then categorized by analyzing the intervention strategy the teacher used. The intervention strategies were adapted from Hofmann and Mercer's study (2016) and included: (1) authoritative, (2) initiating, and (3) continuing interactive strategies.

7 Findings: Teacher interventions in students' joint work

This chapter will present the findings of this study. The results are reported in the order of the research questions. The analysis includes examples of the transcriptions that were transcribed from the video data. The transcriptions have been translated into English with the original Finnish transcription on the right side. In the researched school, a total of six male teachers and two female teachers taught the FUSE lessons. The analysis features examples of four male (John, Greg, Bill and Sam) and one female (Beth) teacher. All names have been changed to ensure the anonymity of participants.

7.1 Situations where teachers intervene in students' joint work

The teachers intervened in the students' joint work in response to many different situations. Students working alone were not included in the analysis since this study focused on how the teachers support students' joint work and collaborative problem solving. However, episodes where an individual student asked for help or came to get the teacher on behalf of a group were included. In addition, episodes where students worked side by side on the same challenge were included if the teacher's intervention was aimed at both students. Interventions were initiated either by a student or by a teacher, which was determined by who initiated the interaction. The ratio of initiations can be seen in Figure 2 and each data example shows whether it was a student or a teacher initiated intervention.

The findings of this study reveal five different scenarios where teachers intervened in students' joint work. These teacher interventions were categorized into five different categories based on the situation and content of the intervention. Table 1 describes the categories and presents an example of each intervention category. STEAM-challenge related interventions were directly connected to a challenge and difficulties in completing a challenge. Difficulties could be associated with the instructions, software or the content knowledge that was required. Disciplinary interventions were connected to situations where students would be

disrupting others or not following the school's rules. Material related interventions were connected to material requests or problems with some materials. These interventions also included translation related problems if challenge instructions or software was only in English. Technology related interventions were connected to the equipment, hardware, and technical difficulties in them. If a student did not know how to use a specific software, this was not categorized as a technical difficulty but as STEAM-challenge related since learning how to use different software was one of the learning objectives in the challenges. Finally, motivation related interventions were connected with situations where students were unwilling to work or focus on given tasks. These were separated from disciplinary interventions since these students were not disturbing others.

Table 1. Examples of teacher intervention categories

The teacher intervention category	**Description**	**Example**
STEAM-challenge related	Situations connected to the FUSE Studio's STEAM-challenges, often difficulties in completing a challenge e.g. understanding the instructions, using the software or having sufficient content knowledge.	Two girls are designing models in the challenge *Keychain Customizer*. They are unsure of the software's commands hence the teacher explains them and guides them forward (see Example 12).
Disciplinary	Situations where students would disrupt others or not follow the rules.	Students are playing on their phones and a teacher refocuses them on task (see Example 3).
Material related	Material requests or problems with materials or translations.	A student needs felt for a challenge and asks the teacher what the word means in Finnish. Student and teacher go searching for felt (see Example 6).
Technology related	Issues or technical difficulties with equipment and hardware.	The speedometer is not working and students ask teacher for help (see Example 7).
Motivation related	Problems with students' motivation towards working on challenges.	Two students do not know which challenge to choose and the teacher attempts to motivate them to start working (see Example 9).

The teacher intervention episodes are categorized below as to what was the situation of the intervention, and whether the intervention was teacher or student

initiated. Figure 1 presents how many of the 55 interventions fell into each category in terms of percentage. Most of the intervention episodes focused on STEAM-challenge related issues (21 interventions, 38%). Second largest category was disciplinary issues (12 interventions, 22%). followed closely by material related problems (11 interventions, 20%). Fourth largest category was technology related problems (8 interventions, 15%). Finally, the least frequent intervention category was motivation related issues (3 interventions, 5%). Figure 2 presents how many interventions were initiated by students and how many by teachers in each category in terms of percentage. While challenge (76%), material (90%), and technology (75%) related interventions were mostly student initiated, most of disciplinary (92%) and all of motivation related (100%) interventions were teacher initiated. Examples from all five categories are presented subsequently in the findings. The first research question aims to answer what kind of intervention episodes arise in a novel learning environment where pairs or groups of students require help. However, if the episodes did not include further interactions, they were not included when analyzing the intervention strategies in the second research question. For example, most of the material, disciplinary or motivation related interventions included only teacher's directions to students and did not necessarily include students' joint problem solving. Hence, they were mostly authoritative and teacher-led. From the 55 episodes that were analyzed in the first stage, eight episodes with further interactions were chosen for the analysis of the intervention strategies (examples 10–15).

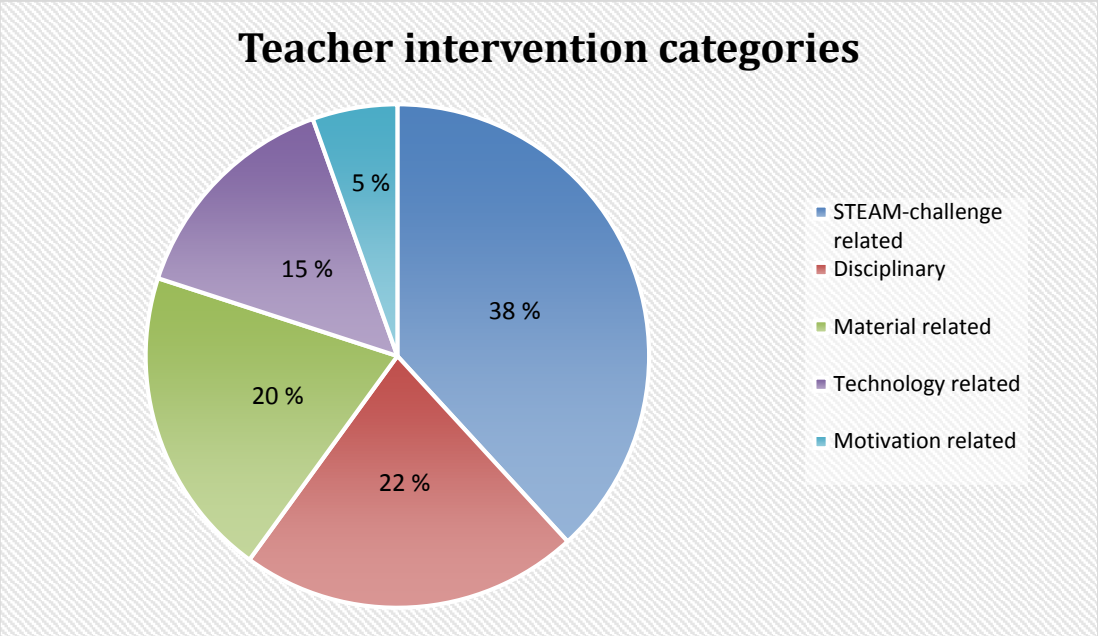


Figure 1. Teacher intervention categories.

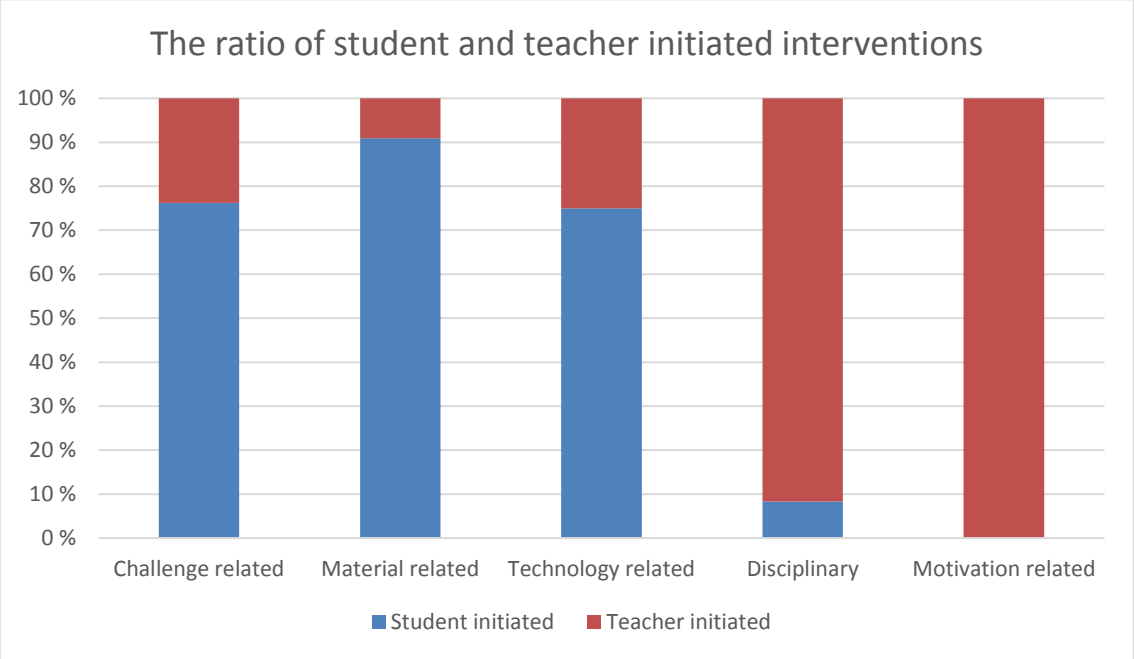


Figure 2. The ratio of student and teacher initiated interventions.

STEAM-challenge related interventions

Interventions related to different STEAM-challenges were the most common (see Figure 1). These interventions were typically initiated by students, although teachers initiated them as well (see Figure 2). On a few occasions, a teacher might ask another teacher for help in solving a student group's problem. STEAM-

challenge related interventions was the category that most often contained further interactions between the teacher and students. Hence, many intervention episodes from this category are analyzed in the second phase in relation to the intervention strategies (see examples 11–15). However, some intervention episodes in this category consisted merely of students asking what to do next e.g. in example 1 (line A1) where students are starting *Coaster Boss*. Especially in the beginning of the fall, it seemed clear that the students were used to teachers having all the answers. Since FUSE has so many different challenges, the idea is that the teacher is not even able to master all of them. Often teachers would try to motivate the students to search for information on the website and in the instructional videos (line A2).

Example 1 (student initiated)

A1. Student 1/Seth: ”What do we do now? What do we do now, we have taken all this stuff?”	A1. Oppilas 1/Seth: “Mitä me nyt tehää? Mitä me nytten tehää, me ollaan otettu nää kamat?”
A2. Teacher John: ”How about you take it to the hallway. And then watch the first video on what you’re supposed to do.”	A2. Opettaja John: ”Te voitte viedä ne vaikka käytävään. Ja kattoa sieltä sen ekan videon, mitä eka pitäis tehä.”

Example 2 (teacher initiated)

B1. Teacher Greg: “Hey, did you get the car to go yet?”	B1. Opettaja Greg: “Saittekste ajaa sen auton jo?”
B2. Students: “No, no.”	B2. Oppilaat: ”Ei, ei.”
B3. T G: “Hey you should move somewhere that the cord reaches. Now it’s keeping it…”	B3. O G: ”Hei kannattaa mennä semmoiseen paikkaan mihin toi johto yltää. Nyt kun se pitää sitä…”
B4. Student 1/Wade: “It does reach.”	B4. Oppilas 1/Wade: ”Se yltää siihen.”
B5. T G: “Okay good, that’s it.”	B5. O G: ”Noni hyvä, just näin.”
B6. Student 2/Ian: “We’re gonna try first a bit shorter [distance].”	B6. Oppilas 2/Ian: ”Me testataan eka vähän lyhempää [matkaa].”
B7. T G: “Yeah, yeah. Can I have a look which [solar] panel you have attached to it?”	B7. O G: ”Joo, joo. Saaks mä vähän vilkasta sitä, mikäs [aurinko]paneeli teillä on kiinni siellä?”
B8. S1/Wade: “We’ve got the bigger one attached.”	B8. O1/Wade: ”Meillä on iso paneeli kiinni.”
B9. T G: “Bigger one? Was it supposed to be the big one?”	B9. O G: ”Isompi vai? Pitikö olla iso?”
B10. S1/Wade: “That’s what it says.” [Boys start testing the lamp and the teacher leaves.]	B10. O1/Wade: ”Näin siellä lukee.” [Pojat rupeavat testaamaan lamppua ja opettaja lähtee.]

In example 2, a group of three boys is working on the challenge *Solar Roller* in the hallway. The teacher has previously helped the group with finding the materials and goes to check on their work (line B1). The teacher asks the group about the materials, namely the cord and solar panel (lines B3, B7). The students seem to know what they are doing and answer the teacher's questions while continuing their work. Ian also explains the reasons behind their actions (line B6), because in the challenge the goal is to make the solar roller move a certain distance. Since it was a teacher initiated intervention, the students would not have necessarily needed help. However, it was a chance for the teacher to check their progress and give them positive feedback (line B5).

Disciplinary interventions

Disciplinary actions were mostly initiated by teachers (see Figure 2). Occasionally another student could come and complain about their own group or another student who was disrupting the work. Teacher would then intervene due to a student's request if they deemed it necessary. Disciplinary situations varied in length. Sometimes intervening actions could take less than 10 seconds (example 3), other times they might take up a teacher's time for almost an entire lesson. In many cases, a teacher would approach a group to remind them of school rules (example 4).

Example 3 (teacher initiated)

[Teacher walks into hallway to check on boys.]	[Opettajaa kävelee käytävään tarkastamaan, mitä pojat tekevät.]
G1. Student 1/Ryan: "They're just playing…"	G1. Oppilas 1/Ryan: "Noku noi vaan pelaa…"
G2. Teacher Greg: "Hey, what game do you have going on here?"	G2. Opettaja Greg: "Hei, mikäs peli teillä on meneillään?"
G3. S1/Ryan: "They're playing Clash Royale…"	G3. O1/Ryan: "Noi pelaa Clash Royalea…"
G4. T G: "Hey, put Clash Royale in your pocket and games away."	G4. O G: "Hei Clash Royalet taskuun ja pelit pois."

In example 3, teacher walks into the hallway where a group of boys are working on *Coaster Boss*. Even though the intervention is clearly initiated by the teacher, the first line is said by the student. It seems that the teacher has good authority since he only approaches the group when the first student is defending why the group work is not coming along (line G1). The teacher has a strong stance with

his arms on his waist which can also be interpreted as a nonverbal sign of authority. The students listen to his first request (line G4) to put the phones away and the intervention ends with the boys scattering and the teacher moving on to help another group. One of the teachers Beth mentions in another video that this sort of disruptive behavior was not an issue in the beginning but at the end of September teachers had to remark students' more about not playing mobile games. She felt it was due to the settling of initial excitement.

Example 4 (teacher initiated)

[Teacher talking to another student.]	[Opettaja puhuu toiselle oppilaalle.]
H1. Teacher Beth: I'll go look for the thread… What are you boys planning to get started with?	H1. Opettaja Beth: ”Mä käyn kattoo sen langan… Mitäs pojat meinaa alkaa tekee?”
H2. Student 1/Mike: ”Why does this have these?” [Referring to tennis balls at a chair's legs]	H2. Oppilas 1/Mike: ”Miks tässä on tämmöset?” [Viittaa tennispalloihin tuolinjaloissa]
H3. Student 2/Vince: “Hey Mike, go sit there.”	H3. Oppilas 2/Vince: “Hei Mike, mee istuu siihen”
H4. T B: ”So they wouldn't make a noise.”	H4. O B: ”Jotta niistä ei kuuluis kolinaa”
H5. S2/Vince: ”NEE-euuu… These wheels are crazy fast.” [Pushing another boy on the chair]	H5. O2/Vince: ”Njauuuu… Sairaan nopeet pyörät.” [Työntää toista poikaa tuolilla]
H6. T B: “Hey! Put the chair back and get to work.” [Boy pushes chair back to teacher]	H6. O B: “Hei! Laita tuoli takaisin ja sit rupee hommiin.” [Poika työntää tuolin takaisin opettajan luo]
H7. T B: “You have a pretty big group doing that one challenge so you could think about diving into…”	H7. O B: “Teillä oli aika iso jengi tekee sitä yhtä haastetta niin vois koittaa miettiä et voisittekste jakaantua…”
H8. Student 3/Freddy: ”Smaller.”	H8. Oppilas 3/Freddy: ”Pienempiin.”
H9. T B: ”Smaller and then do… ” [Boys leave to the hallway]	H9. O B: ”Pienempiin ja tehä sit… ” [Pojat lähtevät käytävään]
H10. [talking to researcher] T B: “Thread was found, thread was already found. Like I do have a bit of a bad conscience for going back and forth.”	H10. [puhuu tutkijalle] O B: “Lanka löytyi, lanka löyty jo. Niinku pienesti tunnen huonoo omaatuntoa et meen täs niinku edestakaisin.”

In example 4, a teacher is trying to help a student when she has to intervene in a group of four boys playing with chairs. Teacher suggests to the group that they might be able to focus better if they divided into smaller groups (line H7). The students seem to have heard this suggestion before (line H8) but do not seem that interested in it since they leave to the hallway before the teacher can finish her sentence. Teacher points out to the videoing researcher that she feels bad

for not being able to focus on one student or group at a time (line H10). Although the school had added teaching resources throughout the fall for FUSE lessons, it seems that it was not always sufficient. Disciplinary related interventions were the second biggest intervention category after STEAM-challenge related interventions (see Figure 1) and some teachers felt that disciplining was time away from helping other students with the challenges.

Material related interventions

Many students seeking for help approached the teacher to ask for specific materials for challenges. Almost all of the material related interventions were initiated by students (see Figure 2). This was despite the fact that all the materials were within the students' reach in material kits or toolboxes in the supply cabinets. Students might have felt that they would get help from the teacher faster than solving the problem themselves. In most cases, teacher would fetch the needed material and bring it to the students. Occasionally, the needed material could not be found or it had finished.

Example 5 (student initiated)

[Teacher is searching for a material kit for two girls.]	[Opettaja etsii materiaalipakettia kahdelle tytölle.]
C1. Student 1/Harris: "John! We need a measuring tape."	C1. Oppilas 1/Harris: "John! Me tarvitaan mitta."
C2. Teacher John: "Wait, what does it say…" [talking to Valerie]	C2. Opettaja John: "Oota mitäs siinä lukee…" [puhuu Valerielle]
C3. Student 2/Valerie: "Can we do it over there?"	C3. Oppilas 2/Valerie: "Voidaanks me tehä tuolla se?"
C4. T J: "Yes."	C4. O J: "Voitte."
C5. S1/Harris: "Is there a measuring tape in the box?"	C5. O1/Harris: "Onks siellä boksissa mitta?"
C6. T J: "Do you need a measuring tape?" [Harris leaves and shouts for the teacher many times]	C6. O J: "Mittaaks te tarvisitte?" [Harris lähtee ja huutaa opettajaa useasti]
C7. Student 3/Adam: "Can I have… Hmm. Can we have those marbles?"	C7. Oppilas 3/Adam: "Saisinko ton, öö, saadaanko me noita kuulia?"
C8. T J: "I'm looking for a measuring tape."	C8. O J: "Mä etin mittanauhaa."
C9. S3/Adam: "Can we have marbles?"	C9. O3/Adam: "Saadaanks me kuulia?"
C10. T J: "Yes. Aren't you 'marble-like'."	C10. O J: "Saatte. Oottepa te kuuliaisia."
C11. S3/Adam: "Where are the marbles?" [looking around]	C11. O3/Adam: "Onks kuulat missä?" [katselee ympärilleen]
C12. T J: "Here." [hands him a marble]	C12. O J: "Täällä." [ojentaa kuulan]
	C13. O3/Adam: "Kiitos."

C13. S3/Adam: “Thanks”.
C14. S2/Valerie: “John. John. John! We can’t find the LED lights in there.”
C15. T J: “No? Let’s find you another [material kit].”
C16. S2/Valerie: “We looked in there and the LED lights weren’t there. There was only paper.”
C17. T J: “Try this but don’t get it mixed with the other ones.”
C18. T J: “Who needed a measuring tape?”
C19. S1/Harris: “We needed a measuring tape!”
C20. T J: “There. Has anyone done the Spaghetti challenge and could help the boys?”
C21. Student 4/Amanda: “I can. I have done it.”
C22. T J: “Amanda, come help the boys.”

C14. O2/Valerie: “John. John. John! Me ei löydetty tosta niitä LED-valoja.”
C15. O J: ”Ette vai? Etitään teille toinen [materiaalipaketti].”
C16. O2/Valerie: ”Me katottiin sieltä niin siellä ei ollu niitä LED-valoja” Siellä oli vaan kauheesti paperituppoja.”
C17. O J: ”Kokeileppa tota, mutta älkää sekottako niitä tota toisien kaa.”
C18. O J: ”Kuka tarviis mittaa?”
C19. O1/Harris: ”Me tarvittiin mittaa!”
C20. O J: ”Tossa. Onks joku tehnyt spagettihaasteen et vois tulla neuvoo poikia?”
C21. Oppilas 4/Amanda: ”Minä osaan. Mä oon tehnyt sen.”
C22. O J: “Amanda, tuu neuvoo poikia.”

Often a teacher might solve several material requests and problems simultaneously since they were overlapping. In example 5, the teacher was standing next to the supply cabinets and many students approached him while searching for materials for different challenges. In under 3 minutes, the teacher was able to help three different groups (groups of student 1, student 2 and student 3) with their material related problems. All groups were working on different challenges, first student’s group on *Spaghetti Structures*, second student’s group on *Coaster Boss* and third student’s group on *Electric Apparel*. All interventions were initiated by students.

Since the teacher was already helping others with material requests and standing close to the supply cabinets, it might have made him seem more approachable. The teacher handled simultaneous requests quite well but he needed extra time to process a new request (line C8) or forgot who was asking for which materials (line C18). In the end, when a group of boys was starting a new challenge, the teacher anticipated that they would soon need help. Hence, he decided to ask other students to help the group (line C20). This can also be seen as an attempt to strengthen relative expertise, which is typical to initiating and continuing interactive strategies (see 7.2.2 and 7.2.3).

Example 6 (student initiated)

D1. Student 1/Hannah: “What is felt?”	D1. Oppilas 1/Hannah: “Mikä on felt?”
D2. Teacher John: “What?”	D2. Opettaja John: “Mitä?”
D3. S1/Hannah: “What is felt?"	D3. O1/Hannah: ”Mikä on felt?”
D4. T J: [sits down at computer and looks at the screen] “Huopa.” [=felt in Finnish]	D4. O J: [Istuu koneelle ja katsoo ruutua] ”Huopa.”
D5. S1/Hannah: “No, there isn’t any felt in there.” [referring to material kit]	D5. O1/Hannah: Ei oo, tuollakaan ei oo huopaa.” [viittaa materiaalipakettiin]
D6. T J: “Is there any felt? Hmm, they might be in the general tool box over there, I’ll go look.”	D6. O J: ”Onks siellä huopaa? Öö ne huovat saattaa olla tuolla yleispakissa, mä käyn ettimässä.”

Material related interventions could also connect to translating problems like in example 6 where two girls were getting started with the challenge *Electric Apparel*. The directions stated that they need felt and that it should be found in the material kit. However, it seems that the directions were not translated since the students ask the teacher to translate the word into Finnish. After this, the teacher and one of the students go find the felt together from the supply cabinets. It is also visible in the example how teachers would often point at a computer screen or in other ways benefit from visual cues on the FUSE website (see Picture 2). Here the teacher wanted to see and check the directions for materials (line D4) even though the student repeatedly asked for felt’s translation and pronounced it clearly (lines D1, D3).

Picture 2. Both students and teachers would often explain or demonstrate things by pointing at the computer screen.

Technology related interventions

Technology related interventions were often initiated by students (see Figure 2). Teachers would initiate technology related interventions usually only if they saw students struggling with certain devices, or knew about a general software problem of which they needed to inform the groups. Teachers would also ask the help of another teacher when they could not solve a technical problem. Interventions were mostly connected to malfunctioning devices e.g. speedometers or software. In many student initiated interventions that were technology related, students needed help with uploading pictures from their phone or camera onto the FUSE Studio website.

Example 7 (student initiated)

E1. Student 1/Paul: “Our meter is not measuring.”	E1. Oppilas 1/Paul: “Tää meiä mittari ei mittaa.”
E2. Teacher Greg: “Did you check that the batteries are in… Have you tried to reset this?” [Teacher takes the meter and looks at it closer.]	E2. Opettaja Greg: ”Katoitsä et siin on paristot… Ootsä kokeillu resetoida tän?” [Opettaja ottaa mittarin ja katsoo sitä lähempää.]
E3. S1/Paul: “We have pressed… Is that how?”	E3. O1/Paul: ”Me ollaan painettu… Ai tollee?”
E4. T G: “I don’t know how to reset this. Take the batteries out and put them back, try that.”	E4. O G: ”Emmä tiiä miten tää resetoidaan… Ota patterit irti ja pistä takaisin, kokeile sillain.”

In example 7, a group of boys was working on the *Coaster Boss* challenge in the hallway. In the challenge, you need to measure the speed of the marble when it comes to the goal. During the intervention, the teacher was in the middle of a discussion with the principal and two reporters. It could have influenced his need to come up with a quick fix even though he did not actually now how to reset the speedometer (line E4). Paul was satisfied with this and went back to the group. However, it was later revealed that the meter had not started working and it required another intervention for the group to be able to finish the challenge. This was a typical example of technology related interventions since teachers often did not know the solution instantly. Thus, they were not able to guide the students but rather investigate the problem themselves and try to fix it. This resulted in authoritative episodes.

Example 8 (teacher initiated)

F1. Teacher Bill: “Hey, if you’re doing that ringtone then try to get it in good shape today because saving it doesn’t work.”	F1. Opettaja Bill: “Hei tota, jos teette ton soittoäänen niin koittakaa saada tänään ne aika hyvälle mallille, koska se tallentaminen ei onnistu.”
F2. Student 1/Jenny: “Okay.”	F2. Oppilas 1/Jenny: ”Okei.”
F3. T B: “So, it could be a good goal to get it, get this one level finished today.”	F3. O B: ”Elikkä, se vois olla hyvä tavoite saada sen, tän yhden tason tehtyä tänään loppuun asti.”
F4. Student 2/Olivia: “Okay. Should we try?”	F4. Oppilas 2/Olivia: ”Okei. Ai yritetään?”
F5. T B: “Mm. Because saving doesn’t work right now.”	F5. O B: “Mm. Koska se tallentaminen ei nyt onnistu.”
F6. S1/Jenny & S2/Olivia: “Okay, yeah.”	F6. O1/Jenny & O2/Olivia: ”Okei, joo.”
F7. T B: “It’s a little… You have to start again next time if you don’t finish.” [Teacher walks over to another group.]	F7. O B: ”Se on vähän… Joutuu kuitenkin sit ens kerralla aloittamaan alusta, jos jää kesken.” [Opettaja kävelee toisen ryhmän luokse.]
F8. T B: “Hey you too, since you’re doing those ringtones, we noticed with the morning group that saving doesn’t work. Or were you able to open saved ones from last time?”	F8. O B: ”Hei teille kans, kun te teette noita soittoääniä niin huomattiin tossa aamuryhmän kanssa et toi tallentaminen ei oo onnistunut. Vai saittekste auki viimekertaiset mitä te olitte tehneet?”
F9. Student 3/Lily: “We haven’t done this one yet.”	F9. Oppilas 3/Lily: ”Ei me olla tätä tehty vielä.”
F10. T B: “Yeah so try to get it today…”	F10. O B: ”Niin eli koittakaa saada tehdä tänään…”
F11. Student 4/Patricia: “I don’t care if it doesn’t work.”	F11. Oppilas 4/Patricia: ”Mua ei haittaa, vaikka se ei toimis.”
F12. T B: “Yeah yeah but try to do it in a way that it’s kinda ready today so you can complete the level and move forward next time.”	F12. O B: ”Niin niin, mut koittakaa tehä siihen malliin että saatte tänään sen tavallaan valmiiksi et saatte nyt sen tason suoritettua niin ens kerralla pääsette sit eteenpäin.

The teacher has noticed with the morning group that saving audio files does not work on *Ringtones* challenge’s software. In example 8, two groups of two girls are working on the challenge and the teacher informs both of them of the malfunction. Although the technical issue is not ideal, the teacher turns it into a motivational factor by asking the students to work hard so they can complete the whole level in one lesson (line F3, F7, F12). Patricia is the only one who implies that she does not care about making progress (line F11) but the teacher does not pay too much attention to this but rather encourages them again to work hard (F12).

Motivation related interventions

Although disciplinary and motivational problems are often connected, they have been separated for this analysis because disciplinary issues were disruptive for the whole group and others around them. Motivational problems refer to intervening situations where students were not disturbing anyone but seemed unmotivated to work on any of the challenges. Similar to disciplinary situations, these were mostly initiated by teachers (see Figure 2). In some cases, students would refuse to work completely or ignore the directions of adults in which case it would require plenty of the teacher's time to motivate them into working.

Example 9 (teacher initiated)

I1. Teacher Beth: "How is it going here?"	I1. Opettaja Beth: "Mites täällä sujuu?"
I2. Student 1/Daniela: "Good. I'm just waiting for that…"	I2. Oppilas 1/Daniela: "Hyvin. Mä venaan et toi on…"
I3. Student 2/Macy: "[inaudible] …I don't know what to do:"	I3. Oppilas 2/Macy: "[inaudible] …Emmä tiiä mitä mä tekisin."
I4. T B: "At this point, almost all challenges have been tried by someone so if you're interested in one, you could go ask what it's like."	I4. O B: "Nyt melkein kaikkia on ainakin joku tehnyt niin sit kantsii kattoo jos joku kiinnostaa niin voi käydä vähän kyselemässäkin että millainen se on."
I5. S1/Daniela: "What to do with these after, what should you do with these?" [referring to a sketch]	I5. O1/Daniela: "Mitä näille sen jälkeen, mitä näille pitää tehdä?" [viittaa luonnokseen]
I6. T B: "Look at the directions, I can't remember now. Were you supposed to upload the plan there to get to the next level? Or was it that you could use the computer software right away?"	I6. O B: "Kato sieltä vielä se ohje, mä en nyt muista ihan ulkoa. Pitiköhän se suunnitelma ladata sinne, et te päästette seuraavalle tasolle? Vai oliks siinä heti et pääsittekste siihen tota tietsikkaohjelmaan?"

In example 9, two girls are on their laptops in a separate classroom and are having difficulties getting started. They have previously worked on the *Jewelry Designer* challenge. The other student is scrolling through the website and has difficulties to choose what challenge to do next (line I3). Even though the problem is not with content knowledge, the teacher attempts to emphasize relative expertise in relation to choosing a motivating challenge (line I4). At the same time the teacher reminds the student of FUSE's interest driven approach. She, along with her classmates, is free to choose which challenge to work on next. The other student asks about the next stage of the challenge (line I5). During the fall term, the school had not been able to get the 3D printer that was required in multiple

challenges including *Jewelry Designer*. This affected the motivation of many students as well since they were only able to draw the sketches but not proceed or complete the challenge.

7.2 Teacher intervention strategies

Next, teacher interventions are presented according to which of the three intervention strategies teachers used when intervening in students' joint work. The intervention strategies: (1) authoritative, (2) initiating and (3) continuing interactive strategies are modelled after Hofmann and Mercer's study (2016). The intervention episodes will be connected to the previously presented teacher intervention categories. The data examples will feature intervention episodes from STEAM-challenge and technology related interventions.

7.2.1 Authoritative strategies

Authoritative strategies refer to intervention episodes where a teacher would be in charge of the solution process (Hofmann & Mercer, 2016). Often this meant that the teacher would not ask questions from the students but would rather guide them step-by-step towards the resolution. Teachers would not make sure, whether the students understood the reason behind each step or if they would have been able to do it independently. Sometimes a teacher might do it completely on the student's behalf. In addition to disciplinary related interventions, which were authoritative by nature, authoritative strategies were especially common in technology related interventions. A typical technology related intervention occurred often when students had to upload digital evidence to the website and a teacher would guide them through it like in example 10. Authoritative interventions would also occur frequently in STEAM-challenge related interventions when a student was learning how to use a certain software like in example 11.

Example 10 (technology related, teacher initiated)

J1. Teacher Greg: "Were you able to film it?"	J1. Opettaja Greg: "Saitteks te kuvattua?"
J2. Students: "Yeah."	J2. Oppilaat: "Joo."
J3. T G: "Okay, let's go through the saving then. Let it be there."	J3. O G: "Okei, katotaas sitte se tallentaminen. Anna olla siinä."
[Teacher helps another student briefly.]	[Opettaja auttaa hetken toista oppilasta.]

J4. T G: “Okay. Then we need to move the mouse. Attach the camera [to the computer] then turn it off and on again.” [Boy does as told.]
J5. T G: “On again. Yes. And then let’s find the mouse. Hey let’s move your structure to the side, so you can work as well. Well you’ve trapped the mouse in here. Why don’t you take this Kyle.” [Moves the structure to Kyle.]
J6. Student 1/Aaron: “Now it’s gonna break.”
J7. T G: “I think we have to tear it down anyways, we don’t have that much time left. Let’s try to get this uploaded so you can continue next time. Okay, sit there and let’s see.”
J8. Student 2/Kyle: “Then we have to do it all over again…”
J9. T G: “You can start tearing it down, Kyle.”
J10. S2/Kyle: [Muttering] “I don’t feel like it…”
J11. T G: “Kyle, you can start tearing it down.”
J12. S2/Kyle: “Yeah, I’ll tear it down in a bit.”
J13. T G: “Yeah. Rest for a bit and then get to work.”
J14. T G: [Talking to Aaron] ”Okay, open Canon Power. Portable devices and there. Keep going, click there. And next. And next. You can find them there, wait. There they are. See which ones are yours.”
J15. S1/Aaron: “These two.”
J16. T G: “Which one… Double click on it once so you can see it bigger and see if it looks good or not. It takes a while to open, just wait.”
J17. S1/ Aaron: “Well this one is better.”
J18. T G: “Okay. See the number there, 5093. Good. Then close the window and go to the FUSE website. Press complete. Then select file. Press computer, there on the left. And then Canon Power Shot. Go ahead. Now find the right one, it was three. There, then the title. What was the challenge you did. And then write here how it went, what went wrong, what went well and worked out. Then write Kyle’s name here so all of your team mates get it saved. Then the send-button over there.” [Teacher leaves.]

J4. O G: ”Okei. Sitten tarttis päästä rullaamaan tällä hiirellä. Onkse kiinni siellä? Pistä kamera sinne [tietokoneeseen] kiinni, sitten sammuttaa ja käynnistää uudelleen. ” [Poika tottelee.]
J5. O G: ”Vielä kerran päälle. Jes. Ja sitten tota etitääs tuolta se hiiri. Hei otetaas tota teiän rakennelmaa vähän sivuun niin säkin pääset tekemään. Te ootte rakentanut tän hiiren tänne sisälle. Otas Kyle tää nytte sinne…” [Siirtää rakennelman Kylelle.]
J6. Oppilas 1/Aaron: “Nyt se menee rikki.”
J7. O G: ”Mä luulen et se ruvetaan nyt purkaa joka tapauksessa, koska ei oo hirveesti aikaa. Koitetaan saada tää ladattua niin pääsette ens kerralla jatkaa sitten. Okei, istuhan vaan siihen niin katotaan.”
J8. Oppilas 2/Kyle: ”Sit me tehään sama juttu seuraavalla kerralla…”
J9. O G: ”Sä voit Kyle purkaa nyt noita tosta.”
J10. O2/Kyle: [Mutisee] ”En jaksa purkaa…”
J11. O G: ”Siitä voi Kyle purkaa noita.”
J12. O2/Kyle: ”Joo mä purkaan kohta.”
J13. O G: ”Noni. Lepäät hetken ja sit ruvetaan hommiin.”
J14. O G: [Puhuu Aaronille] ”Noni siitä Canon Power auki. Kannettavat laitteet ja sieltä. Ja sit siitä vaan eteenpäin, siitä klikkaat. Ja seuraavaan. Ja seuraavaan. Sieltä löytyy, oota. Nyt rupee löytyy niitä. Katoppa mikä niistä ois sun.”
J15. O1/Aaron: ”No nää kaks.”
J16. O G: ”No kumpi… Tuplaklikkaappa sitä kerran niin sä voit kattoa isompana et näyttääks se hyvältä vai ei. Se aukaisee sitä hetken aikaa niin ootat vaan.”
J17. O1/Aaron: ”No tää on parempi.”
J18. O G: ”Okei. Katot tuolta sen numeron, 5093. Hyvä. Sitten vaan ruutu kiinni ja sit sinne Fusen sivuille. Ja tuolta suorita. Sit valitse tiedosto. Ja sieltä tietokone, tuolta vasemmalta. Ja sitten Canon Power Shot siitä. Siitä vaan. Nyt etit sen oikean, se oli se kolme. Noin, nyt sitten otsikko. Mikä tää haaste oli minkä teitte. Ja sen jälkeen kirjoitatte tähän meniks hyvin, mikä meni pieleen, mikä meni hyvin ja onnistui. Sitten kirjoitatte tähän myös Kylen nimen niin saatte kaikkien tiimiläisten talletukseen sen. Sitten tonne lähetä-painiketta.” [Opettaja lähtee.]

Two boys, Aaron and Kyle, have completed the first level of Spaghetti Structures and need help uploading the picture to the FUSE website. The intervention is initiated by the teacher Greg, who has helped them earlier in the lesson and anticipates their need for help. This intervention episode can be interpreted as authoritative already by looking at the transcription. Most of the lines are the teacher's and he speaks much longer than the students do. The teacher does not ask any questions after the initial interaction (line J1).

The intervention episode also includes a disciplinary moment where the teacher asks Kyle to clean up the structure. Aaron has previously indicated his concern towards the structure breaking (line J6). Kyle thinks that if they break it down, they have to start all over again (line J8), probably not knowing that the next level is separate from the previous one. The teacher does not explain this but asks him to tear the structure down. Kyle refuses (line J10) and the teacher repeats his request (line J11). Kyle has had motivation problems in the previous FUSE lessons as well. Finally, they agree that Kyle can take a little break and then start tearing it down (line J13).

This episode demonstrates how the teacher clearly wants the student to do it himself, even if instructed through it. He indicates this by clearing up space for Aaron (line J5) and telling him to sit down in front of the computer (line J7). However, the teacher does not ask the student if he has any previous experience in doing this. Instead of allowing Aaron to find the right steps, he tells him instantly what and where to click (lines J14, J18). Also, after giving the last set of instructions (line J18), the teacher leaves right away without checking whether the students have understood the directions or if they would know how to repeat this next time.

Example 11 (STEAM-challenge related, student initiated)

K1. Teacher Beth: "It's like this." [Referring to the sketch.]	K1. Opettaja Beth: "Se on tällainen." [Viittaa luonnokseen.]
K2. Student 1/Mary: "I accidentally slanted it even more."	K2. Oppilas 1/Mary: "Mä vahingossa vinksautin sitä vielä lisää."
K3. Teacher Greg: "Did you get that mouse? Remember it is easier to draw with it? [Mary goes get the mouse and the teacher sits down at her laptop.]	K3. Opettaja Greg: "Haitsä sen hiiren? Muistatksä sillä hiirellä on helpompi piirtää?" [Mary lähtee hakemaan hiirtä ja opettajaa istuu hänen tietokoneelleen.]

K4. Student 2/Lisa: “I did this stripey, zebra thing. What does it do? Where does it go?”
K5. T B: “Yeah I tried that but it didn’t…”
K6. S1/Mary: “Well it went like this that there is a line in the middle.”
K7. T B: “You can still undo it.”
K8. T G: “Everything can be undone. So what is this, in what way is it slanted?”
K9. S1/Mary: “Well it has gone like this [does a horizontal line with her hand] because…”
K10. T G: “Was it a triangle to begin with?”
K11. S1/Mary: “Yeah.”
- -
K17. S2/Lisa: “Does it work now?”
K18. T G: “I think it’s still… Oh yeah, it looks pretty good now.”
K19. S1/Mary: “Except those two are a little slanted.”
K20. T G: “Well then it’s like that. But yeah. See this is just that you have to remember to look at it from different directions. Because from one perspective it might look good like here but when you look at it from the side, it is a bit slanted. And well.”
K21. T B: “Is it actually now kinda…?”
K22. T G: “Now it’s levelled. It’s okay like this but it’s not like, not like this [shows with hands] but its’ more like you noticed that the square is not quite [even] when you look here.”
K23. S1/Mary: “The corners are not the same…”
K24. S2/Lisa: “How do you get this…”
K25. T B: “Right that’s the one that you can spin it with…”
- -
K41. T G: “But yeah. What I meant was that one option to do a square could be that you make a disc first and then…”
K42. Mary: “Makes the edges narrower.”
K43. T G: “Not even narrower but takes it to the side. With the move-command. Then just sees that it stays level, yep. And lifts it up from there.”
K44. Mary: “Aha.”

K4. Oppilas 2/Lisa: ”Mä tein tällaisen raidallisen, seeprajutun. Mitä tää tekee? Mihin tää menee?”
K5. O B: ”No sitä mä niinku yritin, mutku se ei niinku…”
K6. O1/Mary: ”Noku se meni tällee näin, että siinä keskellä on nyt joku viiva.”
K7. O B: ”Senkin pystyy vielä undo.”
K8. O G: ”Kaiken pystyy vielä undo. Eli mikäs tää piti eli milläs tapaa tää nyt on vinossa?”
K9. O1/Mary: ”No nyt se on mennyt myös tällein [tekee kädellään vaakasuoran viivan] koska…”
K10. O G: “Onks se kolmio alunperin vai?”
K11. O1/Mary: ”Joo.”
- -
K17. O2/Lisa: “Toimiiks nytte?”
K18. O G: “Mä luulen et se on edelleen… Eiku joo, nyt se näyttää aika hyvältä.”
K19. O1/Mary: ”Paitsi nyt noi kaksi on vähän vinossa.”
K20. O G: ”No se on sit semmonen. Mutta tota, joo. Kato tässä on just se, että muistaa katella sitä monesta eri suunnasta, koska yhdestä perspektiivistä se saattaa näyttää ihan hyvältä esim. tästä, mutta sit kun katotkin oikeesti täältä sivusta päin niin saattaa et se onkin vähän sivussa. Ja totaa.”
K21. O B: ”Onkse itse asiassa nytten niinku…?”
K22. O G: ”Siis se on nyt tasossa. Näin se on ihan ok, mutta nyt se ei oo niinku, se ei oo tämmönen [näyttää käsillä] vaan se on pikkasen niinku sä huomasitkin niin se neliö ei oo ihan, kun täst kattoo niin.”
K23. O1/Mary: ”Nää kulmat ei oo sillee samalla…”
K24. O2/Lisa: ”Miten tätä saa…”
K25. O B: ”Niin aivan se oli toi, millä sitä pysty pyörittää.”
- -
K41. O G: ”Mut joo. Se mitä mä meinasin, että yksi vaihtoehto tehä tommonen neliö niin voisi olla on sillain et tekee eka levyn ja sitten tota…”
K42. O1/Mary: ”Kaventaa niitä reunoja.”
K43. O G: ”Ei ees kavenna vaan vie sitä sivulle. Tolla move-komennolla. Sit kattoo vaan et se pysyy niinku tasossa, joo. Ja sitten nostaa sen tosta.”
K44. O1/Mary: “Ahaa.”

In example 11, teacher Beth comes to ask teacher Greg for his help on a software called the SketchUp since he is known as a SketchUp-expert among the teachers. The intervention is initiated by a student, Mary, who is working side by side with Lisa. They are both using SketchUp on their laptops to design their models for *Jewelry Designer*. First, Greg asks Mary to get a separate mouse (line K3) while he sits down on her laptop. Throughout the intervention, Greg operates the software in the student's behalf thus not letting her to try the commands herself. When Mary tries to make a suggestion towards a solution (line K42), the teacher does not agree but explains his own solution.

Although the intervention is initially student initiated, it is not the student but the teacher Beth who fetches another teacher to offer additional guidance. The intervention could have been a collaborative learning opportunity for both teachers as well as both students. That way, it could have provided the students with an example of how teachers also need to work together to learn new ideas. Now it appears more like a situation where Greg is working alone while the others try to see and comprehend what he is doing. Even though Greg tries to explain what he is doing aloud (lines K20, K22, K41, K43), he does not stop to see whether others have understood it. The other teacher Beth tries to offer comments and ideas in the beginning (lines K5, K7, K21, K25) but gives up at some point and leaves to help other students.

The other student, Lisa, keeps listening to the conversation and occasionally stopping her own work to look at Mary's screen. Lisa tries to ask questions about her own work (lines K4, K24), but is only acknowledged when she comments on Mary's design (line K17). Finally, between lines K27–K33, Greg advises Lisa as well until Mary turns the attention back to her own screen. Here, the teacher could have emphasized the interactions between the students for example by asking if they have encountered each other's problems or if they could advice each other. Instead, he answers and guides each of the students separately, even though the girls have been working side by side since the beginning of the challenge.

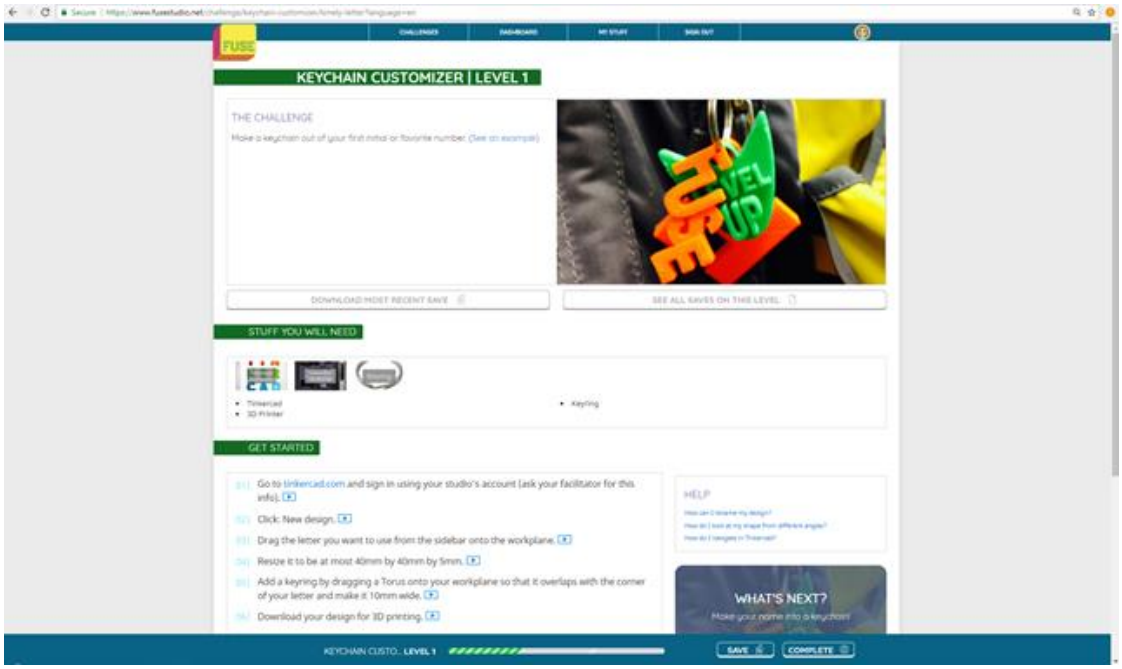
7.2.2 Initiating strategies

Initiating strategies refer to teacher interventions where a teacher invites students to speak, listens to their discussion, refers to the rules of the activity, and focuses students on the task. As a result, the teachers do not take over the entire problem-solving process (Hofmann & Mercer, 2016). Features of initiating strategies could be found in many interventions but the examples were chosen on the basis that the teacher used mainly characteristics from an initiating strategy and that the intervention lead to subsequent interactions between the students.

Example 12 (STEAM-challenge related, student initiated)

L1. Student 1/Mel: “Hey what is this hole thing?”
L2. Teacher Sam: “What thing?”
L3. S1/Mel: “Hole. That hole.”
L4. T S: “Yeah you’re supposed to make a hole there.”
L5. S1/Mel: “What hole?”
L6. T S: “Or what?”
L7. S1/Mel: “No, I mean what is that hole?”
L8. Student 2/Anne: “Yeah, what does it do?”
L9. T S: “Is it that it turns transparent for a while so you can… Click on it again so it goes into the hole-mode.” [Mel clicks.]
L10. T S: ”Yeah so it shows that you can, it turns transparent so you can see through it. If you have that kind of situation that your planning requires you to be able to look through it.”
L11. S1/Mel: “What do we do now that we’re ready?”
L12. S2/Anne: “We should probably look at the video.”
L13. T S: “Look at the directions, I can’t remember by heart.”
L14. S1/Mel: “You’re guiding it now Anne, I can’t be using that thing [the laptop] the whole time.”
L15. S2/Anne: ”Okay. So, let’s continue.” [Clicks open the directions video on the website.]
L16. S1/Mel: “This is so slow… We have done that already.”
L17. S2/Anne: “Okay, new video.” [Students continue watching, teacher leaves.]

L1. Oppilas 1/Mel: ”Hei niin mikä tää on tää hole-juttu?”
L2. Opettaja Sam: ”Ai mikä juttu?”
L3. O1/Mel: ”Hole. Tommonen hole.”
L4. O S: “Niin sun pitäis tehdä tota se reikä siihen.”
L5. O1/Mel: ”Mikä reikä?”
L6. O S: ”Vai mikä?”
L7. O1/Mel: ”Eiku niinku mikä toi hole on?”
L8. Oppilas 2/Anne: ”Niin mitä siit tapahtuu?”
L9. O S: ”Onkse vaan tota et se muuttuu hetken aikaa niinku läpinäkyväksi elikkä sä pystyt… Painappa sitä uudestaan et se menee siihen hole-moodiin.” [Mel klikkaa.]
L10. O S: ”Joo et se näkyy et sä pystyt, tää niinku transparentiksi muuttuu et sä pystyt kattoo siitä läpi, jos siinä on niinku semmoinen tilanne et sun suunnittelu vaatii sitä et sä näät siitä läpi.”
L11. O1/Mel: ”Mitä me tehää nyt kun me ollaan niinku valmiita?”
L12. O2/Anne: ”Meiä pitäisi varmaa kattoo sitä videoo.”
L13. O S:” Kattokaa ohjeita, en mä muista ulkoa.”
L14. O1/Mel: ”Sä nyt ohjaat Anne, mä en nyt voi koko aika tehdä tolla jutulla [kannettavalla tietokoneella].”
L15. O2/Anne: ”Okei. No niin, jatkuu.” [Klikkaa ohjevideon auki nettisivuilla.]
L16. O1/Mel: “Tää oo niin hidas… Me ollaan tehty jo toi.”
L17. O2/Anne: ”Okei, uusi video.” [Oppilaat jatkavat katsomista, opettaja lähtee.]



Picture 3. Challenge directions for *Keychain Customizer*.

In example 12, two girls are sharing a laptop and working together on *Keychain Customizer*. They are designing a model of a keychain but are unsure of the software Tinkercad's commands. After figuring out what their question is, teacher Sam suggests that they try out the hole-command (line L9). He does not do it himself but encourages the students to do it. He then goes on to explain what the command does and why one might use it (line L10). When the students ask what to do next, he guides them to look at the directions (line L13; see Picture 3), like Anne suggests herself (L12). By asking them to do so, the teacher confirms the classroom practice that students should try to use other resources before asking for a teacher's help. At the same time, he refocuses the students on task. This makes Mel assign the computer turn to Anne (line L14) who agrees (line L15). Both strategies can be seen as initiating interactions. When Mel and Anne start looking for the directions, the teacher stays and listens to their discussion. When they are refocused on the task, the teacher leaves.

Example 12, like example 6, demonstrates how the English directions or software could delay getting to work. If the students would have known what "hole" meant, they might have been more willing to experiment with the com-

mand. The teacher also used the English words in his directions without translating them e.g. “hole-mode” and “transparent” (lines L9, L10). It is unclear if the students are able to comprehend the words from context without the teacher probing their understanding.

Example 13 (STEAM-challenge related, student/teacher initiated)

One teacher, John, tried to encourage students systematically to help and work with each other. He would not only do this within groups but also ask individual students to help others or groups of students to help other groups. This could already be seen in example 5, line C20. During one lesson, two girls were working on *Dream Home* side by side, continuously conversing with each other. During the lesson, teacher John did three interventions in the pair’s work. First two were student initiated and the last one was teacher initiated.

M1. Student 1/Tara: “I would like to turn this so I could get to the other side.”
M2. Student 2/Hanna: “Me too, because I don’t even know how to get there.”
M3. Teacher John: “Well wait, let’s see who is furthest along in Dream Home. Eric and Ian, have you rotated the angles there so you can get to the other side of the house?”
M4. Student 3/Rick: “I have!”
M5. Teacher Greg: “Hold down the mouse’s button and then spin.”
M6. T J: “Okay, Rick can come instruct.”
M7. S3/Rick: “What?” [Comes over to the girls.]
M8. S2/Hanna: “How on earth do you turn this?”
M9. T J: “Hold down the mouse and…”
M10. S3/Rick: “What did you want to do?”
M11. S1/Tara: “Rotate the angle.”
M12. S3/Rick: “Take that and then…” [Tara rotates.]
M13. T J: “Which one was it Rick? Why don’t you show me too.”
M14. S3/Rick: “This tool.”
M15. T J: “Oh!”

M1. Oppilas 1/Tara: ”Mä haluaisin kääntää tän sillee, et mä pääsisin tänne toiselle puolelle.”
M2. Oppilas 2/Hanna: ”Niin mäkin, kun mä en tiiä miten sinne niinku pääsee.”
M3. Opettaja John: ”No ootas, katotaan kuka on pisimmällä Dream Homessa. Eric ja Ian, oottekste kääntänyt kuvakulmia siellä että te pääsette talon toiselle puolelle?”
M4. Oppilas 3/Rick: ”Mä oon!”
M5. Opettaja Greg: ”Hiiren nappi pohjassa ja sitten pyörittää.”
M6. O J: ”Okei Rick voi tulla neuvoo.”
M7. O3/Rick: ”Mitä?” [Tulee tyttöjen luokse.]
M8. O2/Hanna: “Miten ihmeessä tätä käännetään?”
M9. O J: ”Hiiren nappi pohjassa ja…”
M10. O3/Rick: ”Ai mitä sä halusit tehdä?”
M11. O1/Tara: ”Kääntää sitä kuvakulmaa.”
M12. O3/Rick: ”Otat ton ja sitten…” [Tara kääntää.]
M13. O J: ”Mikäs se oli Rick? Näytäppä vielä mullekin.”
M14. O3/Rick: “Tää työkalu”.
M15. O J: ”Aa!”

Here, Tara and Hanna have asked the teacher for help with rotating the view so they could see the whole house. The teacher's first response is to find other students to help (line M3). It is unclear whether the teacher knew how to do it himself. However, by asking other students to help, he is constructing an idea that students are the experts on challenges, not teachers. Student Rick is eager to help and comes over to advice the girls. After this, the teacher asks Rick to show him how to do it as well (line M13). By doing so, the teacher indicates that it is acceptable that teachers do not know what to do in all of the challenges. He also reinforces Rick as an expert of the challenge. Interestingly, other teacher Greg exclaims the instructions in the middle of the intervention (line M5), even though he is helping other students at the time. Greg is probably aiming to speed the helping process but it is slightly in conflict with the intervention strategy John is using. Teacher John does repeat these instructions partly (line M9) but then lets Rick to help and explain it to the two girls.

This lesson was in the beginning of September, not long after FUSE lessons had started. The content knowledge on the challenges might have been easier and simpler at that point so it was easier for teachers to harness students' knowledge. However, when a teacher creates collaborative practices in the classroom, it is more likely that students carry on helping each other even when the problems become more difficult.

[Hanna has her hand up and the teacher comes over.]	[Hanna viittaa ja opettaja tulee paikalle.]
M16. S2/Hanna: "Where are all the doors?"	M16. O2/Hanna: ”Missä on niinku kaikkia ovia?”
M17. T J: "What?"	M17. O J: ”Mitä?”
M18. S2/Hanna: "We don't know how to make a door."	M18. O2/Hanna: ”Me ei osata tehä ovee.”
M19. T J: "I think you make it with the squares but let's get someone here again who has [done it]. How about Rick? Rick, have you made doors?	M19. O J: ”Mun mielestä se on niinku noilla neliöillä, mut otetaan taas tänne joku joka [on tehnyt sen]. Rick oisko? Rick ootko tehnyt ovia?
M20. S3/Rick: "Hmm what. I can try."	M20. O3/Rick: "Öö mitä. Mä voin yrittää."
M21. T J: ”Has someone made… Eric, have you made doors?”	M21. O J: "Onks joku tehnyt… Eric ootko tehnyt ovia?"
M22. Student 4/Eric: "I haven't, I'm making thick walls.	M22. Oppilas 4/Eric: ”En oo tehnyt, mä teen paksuja seiniä.”
M23. T J: "Has Ian made doors?" [Ian's answer is inaudible.]	M23. O J: ”Onks Ian tehnyt ovia?” [Ianin vastaus ei kuulu.]
M24. T J: "Has Jesse made doors?"	M24. O J: ”Onks Jesse tehnyt ovia?”

Here the situation is left unresolved despite the teacher's efforts to find someone who knows how to make doors. In the end, the teacher gets distracted with another help request. It could be argued that the teacher should have spent more time with the girls since he suggests he might know the answer (line M19). But the girls do not seem to bothered with not getting an answer and keep working on other aspects of their houses. Again, just by asking many students whether they know how to do it, the teacher creates interactive procedures within the entire class.

In the previous intervention, Rick was able to help the girls. Now he is unsure whether he knows how to build doors. Despite that, he is willing to try (line M20) and comes over to the girls' computer to see if he could help. It could be that by asking Rick to help in the previous intervention, the teacher has built his confidence and willingness to help others and reinforced his status as a *Dream Home* expert.

M25. T J: "Have you girls saved yours yet?"
M26. S1/Tara: "Not yet."
M27. T J: "You could save them so they'll be safe for next time."
M28. S2/Hanna: "Yeah I saved it already last time."
M29. T J: "Good, then you can, if you have the same file, just click on save."
M30. S1/Tara: "I have the same file too."
M31. T J: "Were you able to make progress this time?"
M32. S2/Hanna: "Yeah I got the walls done and some windows."
M33. T J: "Oh nice."
M34. S1/Tara: "I don't like get that where, where the save is."
M35. T J: "What don't you realize?"
M36. S1/Tara: "That where the save [button] is."
M37. T J: "Oh, I'll guide you. There, file. Go up up, left, left, there. And then go back, there. Right there. And then it saves it."
M38. S1/Tara: "Okay."
M39. T J: "Now it's saved, then you can close."

M25. O J: "Oottekste te tytöt tallentanut ne teidän?"
M26. O1/Tara: "Ei vielä."
M27. O J: "Te voisitte tallentaa et ne säilyy ens kerraksi.
M28. O2/Hanna: "Joo mä tallensin jo viime kerralla."
M29. O J: "Noni hyvä, sitten sä voit jos sulla on sama tiedosto niin painaa pelkkää sitä "save".
M30. O1/Tara: "Mullakin on tää sama tiedosto."
M31. O J:"Pääsittekste eteenpäin tällä kerralla?"
M32. O2/Hanna: "No mä sain tehtyä seinät ja vähän ikkunaa."
M33. O J: "Aa kiva."
M34. O1/Tara: "Mä en niinku tajuu et mistä, et missä se save muka on."
M35. O J: "Ai mitä et tajua?"
M36. O1/Tara: "Et missä se save [painike] on:"
M37. O J: "Aa mä neuvon sua. Sieltä file. Meet ylöspäin ylöspäin, vasemmalle vasemmalle, siinä. Ja sitten siihen äskeiseen, siellä. Siinä. Just se. Sit se tallentaa sen."
M38. O1/Tara: "Okei."
M39. O J: "Nyt se on tallentanut, sit voit sulkea."

- -	- -
M45. S2/Hanna: “Where can you get the windows…”	M45. O2/Hanna: ”Mistäköhän saa ne ikkunat…”
M46. S1/Tara: “Not now, you have to save. [click on] File.”	M46. O1/Tara: ”Ei nyt pitää tallentaa. [Klikkaa] File.”
M47. S2/Hanna: “File…” [clicks]	M47. O2/Hanna: ”File…” [klikkaa]
M48. S1/Tara: “Yeah and then save. [Where it says] just save.”	M48. O1/Tara: “Joo ja sitten save. [Missä lukee] pelkkä save.”

The third intervention is a good example of how using initiating strategies for one lesson, can already have an effect on students’ actions. Here, the teacher intervenes the pair’s work in order to ask them to save their work since the lesson is ending (line M25). He also uses the opportunity to ask about the pair’s progress and give them feedback (lines M31, M33). Tara cannot remember how to save the file so the teacher guides her through it authoritatively. However, in the end John makes sure to explain when the saving has gone through and when the student can close the software (line M39). Soon after the teacher has left, Hanna is wondering about windows for the house (line M45). Tara tells her that she does not have time for it (line M46) and instruct her through the saving process (line M48). Therefore, the initiating strategy the teacher used resulted in continuing interactions between the students.

7.2.3 Continuing interactive strategies

Continuing interactive strategies refer to teacher interventions where a teacher repeats students’ relevant ideas, probes and explores students’ understanding, encourages students to compare and test ideas, and identifies resources for thinking (Hofmann & Mercer, 2016). Surprisingly, interventions with purely continuing interactions were not frequent in the data. The first example analyzes an intervention where a teacher used mostly continuing interactive strategies while the next example features some characteristics of this strategy and some from other strategies. Although the examples feature *Dream Home*, these intervention strategies were found in other challenges as well.

Example 14 (STEAM-challenge related, student initiated)

N1. Student 1/Mia: “So I watched the video here…”	N1. O1/Mia: “Niin kun mä kävin kattoo sen videon täältä…”
N2. Teacher John: “Yeah, does it have the ridge roof? Right.”	N2. O J: ”Joo onks siinä harjakatto? Just niin.”

N3. S1/Mia: “Yeah but when I watched the video, I didn’t understand. I tried to use that thing to do it and I tried to raise it but it doesn’t rise and then something weird happens.”
N4. T J: “Okay, let’s look at it together. Let’s see if I can help, I have lifted it before when we tried this. But I remember that it was hard, mine was a bit slanted too. Let’s see, now it [the video] shows where to take it. Did you get that far?”
N5. S1/Mia: “Yeah, I got to that pen.”
N6. T J: “Pen. Good, that we have understood.”
N7. S1/Mia: “And then it just draws that line. I don’t get it because she [Grace] gets a red dot, I get a pink dot.”
N8. T J: “I don’t think it matters. Let’s see in a bit.”
N9. S2/Grace: “It does.”
N10. T J: “Does it? That might make a difference then. So you have to draw it to the edge. Should we hit stop now and see if we can get this far? Then take the pen… Do you wanna try?” [Mia takes the mouse.]
N11. T J: “Yeah probably when it’s there at the edge, which means reunassa, [teacher translates the word] it makes a point there. Like there, mid-point. Should you pull it from the middle towards it? [Mia tries different ways.] And there. Right. Then we move on to the next phase. [Mia goes back to the website to check on the video.]
N12. S2/Grace: “It said ‘unphased’. [Inaudible for transcription]”
N13. T J: “Should it say ‘unphased’ or?”
N14. S2/Grace: “I think so, let’s see.”
N15. [looking at the website directions] T J: “On edge. Didn’t it say on edge for us?”
N16. S1/Mia: “Yeah I didn’t notice.”
N17. T J: “Wait what does it say there, continue drawing. Continue drawing until you reach the back edge. We did that. [Mia nodding.] So we are at this stage. Click to finish drawing your line. Yeah we did that and now we have that black. [Mia nodding.] I feel like we’re at this point now. Now we need

N3. O1/Mia: “Joo kun mä katoin tän videon, mutta mä en niinku ymmärtänyt. Mä yritin tehä tolla jutskalla sen jutun sinne ja mä yritin nostaa sitä, mut se ei vaan nouse ja sit tapahtu jotain outoo.”
N4. O J: ”Noni, katotaan yhdessä. Katotaan, jos mä osaan auttaa, mä oon kerran nostanut, kun me kokeiltiin tätä. Mutta mä muistan et se oli vaikee, mulla tuli itelläkin siitä vähän vino. Katotaan, nyt se [video] näyttää kohta et mistä täältä se otetaan. Pääsitsä siihen asti?”
N5. O1/Mia: ”Joo pääsin et toi kynä.”
N6. T J: ”Kynä. Hyvä, se me ollaan ymmärretty.”
N7. O1/Mia: ”Ja sit se vaan vetää tästä tollasen viivan. Mä en niinku tajuu ku sille [Gracelle] siitä tulee tollanen punanen piste, mulle siitä tuli sellainen vaaleanpunainen piste.”
N8. O J: ”Mä en usko et sillä on ehkä väliä. Katotaan kohta.”
N9. O2/Grace: ”On sillä.”
N10. O J: ”On vai? No se voi olla se ratkaiseva sitten. Eli sun pitää vetää se tonne laidalle asti, painetaanks tässä stoppia ja kokeillaan päästäänks me näin pitkälle? Sit otetaan se kynä… Haluutsä ite kokeilla?” [Mia ottaa hiiren.]
N11. O J: ”Niin se varmaan, kun se on siinä kohdassa siinä edgessä elikkä siinä reunassa, se tekee siihen eri pisteen. Tosta vaikka, mid-point. Pitäiskö sun vetää just siitä keskeltä sitä sinne? [Mia koittaa eri keinoja.] Ja siihen. Noin. Sitten mennään seuraavaan vaiheeseen.” [Mia palaa nettisivustolle katsomaan ohjevideota.]
N12. O2/Grace: “Siinä luki tai ’unphased’.” [Sanasta ei saa selvää.]
N13. O J: ”Pitäiskö siinä lukee ’unphased’ vai?”
N14. O2/Grace: ”Muistaakseni, katotaan.”
N15. [Katsoo nettisivun ohjeita.] O J:”On edge. Eiks meillä lukenut siinä on edge?”
N16. O1/Mia: ”Joo en mä huomannut.”
N17. O J: ”Ootappa mitä se sanoo tossa, continue drawing. Continue drawing until you reach the back edge. No se me tehtiin. [Mia nyökkää.] Me ollaan tässä vaiheessa. Click to finish

to lift the line up to make. Yeah now we have to lift it and it shows where to lift it, there. Did you get to this point last time?
N18. S1/Mia: “Yeah. But I just didn’t know how, it just didn’t rise.”
N19. T J: “Well, let’s see. Click on the line you just drew…”
N20. S2/Grace: “When I tried, the line rose instead of the ridge roof.”
N21. T J: “Right the line. At the moment your…”
N22. S2/Grace: “But not the roof. The line rose off the roof!”
N23. T J: “But it could be that you do it [the line] first and the ridge roof later. So you kind of lift it… [looking at the video] Oh no, it is supposed to be a ridge roof [right away].
N24. S2/Grace: “Yeah but it didn’t raise the roof from it…”
N25. S1/Mia: “Yeah it raises that line.”
N26. S2/Grace: “Yeah last time it raised that line.”
N27. S1/Mia: “Look, that’s what happens. [Teacher uses the mouse and students refer to the screen.]
N28. S2/Grace: “Can I, because I’ve done a ridge roof?”
N29. T J: “Yeah you can, wait. Let’s undo move. Here you can always go back.”
N30. S2/Grace: “Doesn’t Ctrl+Z work too?”
N31. T J: “Yeah.” [Gives the mouse to Grace.]
N32. S1/Mia: “It’s easier to use. It’s just doesn’t somehow, this just happens. [Explains while Grace is trying.]
N33. T J: “You know, you must have another tool on, you have one that moves it.”
N34. S1/Mia: “Press Ctrl+Z.”
N35. T J: “You are at another view.”
N36. S2/Grace: “Now the line went away.”
[Students talk to each other, teacher stays in the background. Girls keep trying together, Grace is now using the mouse and Mia keeps giving her directions]

drawing your line. Joo se me tehtiin ja nyt meillä on tommonen musta. [Mia nyökkää.] No nyt musta tuntuu et me ollaan tässä kohdassa. Now we need to lift the line up to make. Joo nyt meidän pitää nostaa se ja nyt se näyttää mistä se nostetaan, tosta. Pääsitsä viimeksi tähän vaiheeseen?”
N18. O1/Mia: ”Joo pääsin. Mut mä en osannut vaan, se ei vaan noussut.”
N19. O J: ”No katotaan. Click on the line you just drew…”
N20. O2/Grace: ”Kun mä kokeilin niin nous se viiva, eikä harjakattoa.”
N21. O J: ”Niin se viiva. At the moment your…”
N22. O2/Grace: ”Mut ei kattoa. Se viiva nousi katosta irti!
N23. O J: ”Mut se voi olla et se tehdään ekaksi se [viiva] ja se harjakatto tehään myöhemmin. Et se nostetaan. [Katsoo videota.] Eiku harjakattohan siitä tulee [heti].”
N24. O2/Grace: ”Eiku se ei nostanut sitä kattoa siitä…”
N25. O1/Mia: ”Niin vaan se nostaa ton viivan.”
N26. O2/Grace: ”Niin se nosti viimeks ton viivan.”
N27. O1/Mia: ”Kato sille tapahtuu tollee. [Opettaja käyttää hiirtä ja oppilaat viittaavat ruutuun.]
N28. O2/Grace: ”Saanks mä, kun mä oon tehnyt harjakaton?”
N29. O J: ”Joo saat oota. Mennään tota, undo move. Täältä pääsee aina taaksepäin.”
N30. O2/Grace: ”Eiks Ctrl+Z:stakin pääse?”
N31. O J: ”Joo.” [Antaa hiiren Gracelle]
N32. O1/Mia: “Se on helpompi käyttää. Tää ei vaan jotenkin, tällee vaa tapahtuu.” [Selittää sillä välin kun Grace kokeilee.]
N33. O J: ”Siinä on tiiätkö sulla varmaan nyt joku toinen tool päällä, sulla on joku semmonen et siirrä tätä.”
N34. O1/Mia: ”Paina Ctrl+Z.”
N35. O J: ”Sä oot jossain toisessa näkymässä.”
N36. O2/Grace: ”Nyt se viiva lähti.”
[Oppilaat puhuvat toisilleen, opettaja pysyttelee taka-alalla. Tytöt jatkavat yrittämistä yhdessä, Grace käyttää nyt hiirtä ja Mia antaa hänelle ohjeita.]

In example 14, two girls are working on *Dream Home* next to each other on separate computers. Mia has asked the teacher for help with building a ridge roof. Previously John has stated to all students that they should check other resources e.g. the website before asking a teacher for help. Mia has clearly learned this since she initiates the intervention by stating that she has read the instructions and watched the video but still does not understand (lines N1, N3). From the beginning, the teacher uses strategies that support continuing interactions. The key feature of this strategy is that it does not intend to close down the discussion by coming to a solution as quickly as possible, but rather encourages students to presents their ideas and probes their understanding. The teacher does this by involving both students in the solution process. He listens and comments on their ideas (lines N10, N21, N23) and makes an effort in understanding which stage the students got to independently (lines N4, N17). He does not overlook their suggestions even if he thinks they are not necessarily relevant (lines N8, N10). The teacher repeats relevant ideas (line N6) and asks applicable questions (lines N13, N15) in order to reinforce their thought process. He gives turns to both students and makes sure that they are using the mouse instead of the teacher (lines N10, N29).

Some features of the intervention episode are slightly authoritative. For example, the teacher could have accentuated the students' lead in the process. During lines N11 and N17, he is reading the directions aloud. Even though he is checking that the student is following through nonverbal communication, e.g. Mia nodding and following the screen, but in order for the episode to be pu John could have asked Mia to read and explain the next steps. In addition, he could have encouraged the students to converse with each other more, now he seems to occasionally act as a mediator in the discussion (lines N8, N13, N15). Even when including these details, the teacher is generally using the characteristics of a continuing interactive strategy.

Line N11 is an interesting example because the teacher is probing the student's understanding but doing it through looking at the computer screen and observing the student's choices. Even though Mia is not saying anything aloud, the teacher keeps encouraging her to test her ideas by trying different commands and seeing what they do. At the end of the line, the teacher mentions that they

will move on to the next phase. Without clarifying further, Mia knows that this means that they should look at the instructions video and goes back to the website. This is a clear indication of how learning in a digital environment may not always look or sound like traditional learning. Hence, the teacher needs to be aware of how to intervene and support learning in situations where students may not be expressing themselves verbally.

Unlike in example 11, Grace is involved throughout the problem-solving process. First by commenting and giving suggestions (lines N9, N14, N20, N26) and then by trying to solve it herself (line N28). Although both girls are working on their own projects and houses, they clearly help each other through the process. Grace does not seem to mind putting her own project on hold while they try to solve Mia's problem.

N42. T J: "We can't raise that roof."
N43. Teacher Greg: "What do you want, do you want to do the ridge roof there?"
N44. S1/Mia: "Yeah a ridge roof but it doesn't work."
N45. T G: "How have you usually done it?"
N46. T J: "Lifted it from there but it might be at another view now. The problem might be with the view."
N47. T G: "You are too close to it now, let's go…" [Greg starts using the mouse.]
N48. S2/Grace: "I did it close like that."
N49. T G: "Which tool is this that you have on?"
N50. T J:"Do we have the wrong tool on?"
N51. S2/Grace: "No because it [the video] showed that one.
[Greg keeps trying]
- -
N56. T G: "Oh do you want to lift it? It's that tool.
N57. S2/Grace: "No it's not."
N58. T J: "It did say in the directions that it's that one [the one girls have been using].
N59. T G: "Oh, okay. Well then. Then it's a different system."
N60. S1/Mia: "But here it just goes like that…"
[Both teachers leave to help others that have asked for help.]

N42. O J: "Me ei saada nostettua tota kattoa."
N43. Opettaja Greg: "Mitä te haluutte, haluutteks te tehdä sen harjakaton siihen?"
N44. O1/Mia: "Joo harjakaton, mut se ei onnistu."
N45. O G: "Milläs tapaa sitä on yleensä tehty?"
N46. O J: "Tosta on nostettu, mut tuo on nyt jossain ehkä muussa näkymässä. Se ongelma on ehkä toi näkymä."
N47. O G: "Te ootte nyt liian syvällä siinä, mennääs tota…" [Greg rupeaa käyttämään hiirtä.]
N48. O2/Grace: "Mä tein sen tolleen läheltä."
N49. O G: "Mikäs tää on tää työkalu mikä teillä on valittuna?"
N50. O J: "Onks meillä väärä työkalu päällä?"
N51. O2/Grace: "Ei koska se [video] näytti sitä."
[Greg jatkaa yrittämistä.]
- -
N56. O G: "Ai sä haluut nostaa sitä vai? Se on toi työkalu."
N57. O2/Grace: "Ei ole."
N58. O J: "Se kyllä sano siinä ohjeessa et se ois tuo [jota tytöt ovat käyttäneet.]
N59. O G: "Aijaa, okei. No sitten. Sit se on eri systeemi vaan."
N60. O1/Mia: "Mut tossa vaan tapahtuu tollee et…"
[Molemmat opettajat lähtevät auttamaan muita oppilaita, jotka ovat pyytäneet apua.]

After teacher John and the two students have been trying to solve the problem for a while, teacher Greg walks by. John asks him for help. In previous examples, teacher Greg's intervention strategies have been authoritative and he uses the same approach here. After clarifying what the problem is (line N43), Greg's questions and comments are aimed at the other teacher (lines N45, N49) who then answers them (lines N46, N50). Grace tries to contradict Greg's suggestion by stating that she has been able to do it with the close-up view (line N48) but her comment is overlooked. Next Greg starts using the mouse on the student's behalf. Greg does not seem to be sure about how to build a ridge roof. He suggests that the problem is with the tool they are using (lines N49, N56) but Grace disagrees by using the directions as an evidence to support her claims (lines N51, N58). Instead of acknowledging or praising Grace's comments, Greg does not answer them. Only when John agrees with Grace (line N58), Greg stops trying. When Mia presents a final observation (line N60), both teachers are approached by other students and leave to help them. In this case, Greg's authoritative approach ends the previous intervention that John had made using a continuing interactive strategy. However, eight minutes later John comes back to check on the students' progress. Mia answers that they are coming along well because Grace told her what to do since she is further along in the challenge. John gives them positive feedback and comments to the girls that the main idea of FUSE is to help a friend. Hence, it could be estimated that on some level, the initial intervention encouraged Mia and Grace to continue collaborative problem solving.

Example 15 (STEAM-challenge related, student initiated)

O1. Teacher Beth: "And hey, here [pointing at the screen] you can see, this is actually kinda nice that it shows who else is working on this. None of them are here now though. Yeah. But if someone was then you could ask them directly.	O1. Opettaja Beth: "Sit hei tästä [osoittaa ruutua] sä voit kattoo, tossa on itse asiassa aika kiva et tossa näkyy et ketkä muut on tekemässä tätä. Noi ei oo kyl kukaan nyt täällä. Joo. Mut jos siellä ois joku niin sit pystyisi kysyy suoraan."
O2. Student 1/Kia: "You could, hmm, now go help Paula because she will also go to level two soon."	O2. Oppilas 1/Kia: "Sä voisit öö, nyt mennä auttamaan Paulaa, koska sekin menee kohta kakkostasolle."
O3. T B: "Or you could help Paula when she needs help. That could be better."	O3. O B: "Tai sä voisit käydä auttamassa Paulaa sit kun Paula tarvii apua. Se vois olla parempi."
O4. S1/Kia: "But I don't remember yet how to do it."	O4. O1/Kia: "No kun en mä vielä muista miten se tehdään."

O5. T B: “You only had to save and then upload. I can come next to you so you can then ask me. [Moves next to Paula.] Paula, is yours ready besides saving?”
O6. Student 2/Paula: “Almost. But I don’t know how to do it, hmm, how do I get the second level because I want go inside here.”
O7. T B: “Can you help Kia? How to get to that…”
O8. S2/Paula: “Second level.”
O9. T B: “Oh second level! [Smiling and looking at Kia.] Well come and see, let’s see if. Because then you have to do the same thing when you go from second to third level. [Kia comes over.] So Paula, have you saved the latest one?”
O10. S2/Paula: “Hmm not yet.”
O11. T B: “Well where could you save it from?”
O12. S2/Paula: “I don’t know.”
O13. T B: “Where do you usually save when you do something on the computer?”
O14. S2/Paula: “I don’t know, I never do anything on the computer.”
O15. T B: [to Kia] “Do you remember where to save?”
O16. S1/Kia: “Was it there?” [Pointing at File-button on the screen.]
O17. T B: “Yes. File.” [Paula clicks on File.]
O18. S1/Kia: “Was it that one?” [Points at Save as -button.]
O19. T B: “Save as. Yes. Great. [Paula saves.] Yes! And then what?”
O20. S1/Kia: “Hmm, then we go to that weird website.”
O21. T B: “Fuse website, yes. Next, yeah.”
O22. S2/Paula: “Save your work.”
O23. T B: “Yeah, there ‘Upload your work’. There, and what did we do now?
O24. S1/Kia: “Browse!”
O25. T B: “Browse, yes.”
O26. S2/Paula: “That one or then that one?” [Points at screen.]
O27. T B: “You could write it actually there so it’ll search for it. There, then press enter. [Paula keeps her finger over the button] Exactly that big one. Yes. Click there that ‘My’ and it’ll search there.”

O5. O B: ”Ei se tarvinnut kun tallentaa ja sit ladata. Mä voin tulla tähän viereen niin sit voitte kysyä multa. [Siirtyy Paulan viereen.] Onks sulla Paula tallennusta vailla?”
O6. Oppilas 2/Paula: ”Melkein. Mut kun mä en osaa tehdä tota, hmm, et miten mä saan sen tokan levelin, kun mä haluun mennä sisälle tänne.”
O7. O B: ”Osaatsä Kia auttaa? Et miten pääse tonne niinku…”
O8. O2/Paula: ”Toiselle levelille.”
O9. O B: ”Aa toiselle levelille! [Hymyilee ja katsoo Kiaa.] No tuu kattoo, katotaan jos. Koska sitten sun pitää tehdä sama homma, kun sä meet kakkoselta kolmoselle. [Kia tulee.] Niin, eli oot sä tallentanut ton Paula, ton viimeisimmän?”
O10. O2/Paula: ”Öö en oo vielä.”
O11. O B: ”No mistä sen vois tallentaa?”
O12. O2/Paula: ”En mä tiedä.”
O13. O B: ”Mistä yleensä tallennetaan, kun sä teet tietokoneella jotakin?”
O14. O2/Paula: ”En mä tiedä, en mä tee ikinä tietokoneella mitään.”
O15. O B: [Kialle] ”Muistat sä mistä tallennettiin?”
O16. O1/Kia: ”Oliks se tuolta?” [Osoittaa File-nappia ruudulla.]
O17. O B: “Oli. File.” [Paula klikkaa File-nappia.]
O18. O1/Kia: “Oliks se toi?” [Osoittaa Save as -nappia.]
O19. O B: “Save as. Kyllä. Loistavaa. [Paula tallentaa.] Jes. Mitäs sitten tehtiin?”
O20. O1/Kia: ”Öö, mentiin sinne ihme sivulle.”
O21. O B: ”Fusen sivulle, kyllä. Seuraava, joo.”
O22. O2/Paula: ”Tallenna työsi.”
O23. O B: ”Jes, siellä ’Lataa työsi’. Noin, ja mitäs nyt tehtiin?”
O24. O1/Kia: ”Selaa!”
O25. O B: ”Selaa, kyllä.”
O26. O2/Paula: ”Vai toi vai sitten toi?” [Osoittaa ruutua.]
O27. O B: ”Sä voisit kirjoittaa sen itse asiassa tonne niin se hakee sen. Noni sit paina enter. [Paula pitelee sormeaan enter-napin yllä.] Just se iso. Kyllä. Paina tuolta toi omat niin se hakee sen sieltä.”

Initially student 1, Kia, has asked the teacher for help in saving and uploading the first level of *Dream Home*. The teacher guides her through it authoritatively and in the end gives her a hint about a feature on the FUSE website that shows which students are working on the same challenge (line O1). By doing so, the teacher implicates that next time the student could ask for a friend's help before relying on the teacher. Another student, Paula, is working on the same challenge at the next desk over. This example demonstrates how teacher could support continuing interactions even when the students are working on separate computers at a different pace. Kia believes that Paula will need help moving on to the second level and suggests that the teacher would help her (line O2). Beth believes that Kia could now help her instead, since she has learned how to save and upload (line O3). Kia seems hesitant so the teacher promises to stay next to the girls and help if necessary.

Paula claims that she has not saved anything on computers before (lines O12, O14). This is unlikely since she is a fifth grader and even if she had not used a computer at home, she has used one at school before. It could be that she hopes that her responses would make the teacher tell her the right answers. However, Beth does not resort to authoritative strategies yet. First, she tries to identify resources for thinking by asking Paula to find the solution through her previous experience with computer programs (line O13). When this does not help, the teacher asks Kia instead if she knows how to help Paula (line O15). The students need more help than the teacher might have expected. Therefore, she supports their mutual interactions by asking the appropriate questions (lines O15, O19, O23) and probes Paula's understanding through her answers (lines O16, O18, O20, O24). When Paula points to or finds the right button, the teacher voices this by saying the command's name aloud (lines O17, O19, O21, O25).

Similar to example 14, occasionally the teacher has to explore the student's understanding by looking at what they are doing on the screen (lines O16 to O19) or on the keyboard (line O27). For instance, the teacher notices Paula's hesitation when she is asked to press enter-button. When Paula finds the button, the teacher quickly confirms her choice and gives her feedback for finding it (line O27). After this, they encounter some more difficulties with saving and the teacher guides Paula through it more authoritatively. This could also be because

another student comes to get feedback from the teacher and Beth has to balance with two simultaneous interventions. Meanwhile Kia asks for a permission to return to her own work.

7.3 Summary of results

A total number of 55 teacher interventions were analyzed. Five main scenarios were found as to why teachers intervened in students' joint work. The five categories were the following from the most frequent to least frequent: STEAM-challenge related, disciplinary, material related, technology related, and motivation related interventions (see Figure 1). Four of the categories included both teacher and student initiated interventions. While challenge, material, and technology related interventions were mostly student initiated, disciplinary related interventions were mostly teacher initiated. Motivation related interventions were entirely initiated by teachers.

From the 55 interventions, eight intervention episodes that had further interactions between students and teachers after the initial intervention were chosen for further analysis. The eight intervention episodes featured are STEAM-challenge and technology related. These intervention episodes were analyzed to examine the different intervention strategies teachers used when intervening in students' joint work. Examples of all three intervention strategies were found. However, while some interventions were purely authoritative, and some used almost entirely initiating strategies, interventions with purely continuing interactive strategies were not found. There were differences between teachers and the strategies they used. While some used mostly authoritative strategies, one teacher in particular used mostly initiating and continuing interactive strategies. As expected, almost all of the disciplinary related interventions included the teacher using authoritative strategies. These strategies were also common in technology related interventions. In STEAM-challenge related interventions, authoritative strategies were typical when a teacher advised students about new software. Initiating strategies were found in STEAM-challenge related interventions. When using these strategies, teachers often encouraged students to communicate with each other and the intervention often lead to further interactions between the stu-

dents. By doing so, teachers created continuing interactions between peers. Continuing interactive strategies were used in STEAM-challenge related interventions as supporting strategies. Even as a supporting strategy, continuing interactive strategies resulted in collaborative problem solving between students.

The analyzed teacher interventions varied in length. While some lasted several minutes, especially disciplinary interventions could take less than 10 seconds. Previous research states that the intervention length affects the quality of an intervention (Ding et al., 2007). Studies have also shown that the positive effects of an intervention last a minimum of 5 minutes but then gradually fade (Chiu, 2004). Hence, it can be interpreted as effective that some teachers would revisit the group after the initial intervention to see if students had found a solution that was not reached in the intervention before (example 14).

Often a student would show their involvement and understanding nonverbally, for example by using the computer or mouse or pointing at the screen (examples 13 and 14). These examples were a distinct indication of how learning in the 21st century may not always look or sound like traditional learning. Hence, the teacher needs to be aware of how to intervene and support learning in situations where students are not expressing themselves verbally and thus look as if they are not participating or collaborating.

8 Ethical considerations and reliability

In this chapter, the reliability of this research will be discussed. Since the study's data consisted of video material that was collected by videoing both children and adults, special attention will be paid to the ethical considerations.

8.1 Ethical considerations

Evaluating the reliability i.e. the possibility to replicate the results is challenging with human behavior since it is constantly changing (Merriam, 1998, 205). Hence, Merriam (1998, 206) suggests that findings do not need to be the same if the study is replicated but reliability should rather be indicated by results that are "consistent with the data collected". One technique is the *audit trail* where the researcher describes in detail how data were collected, how it was categorized, and how decisions were made all through the investigation (Merriam, 1998, 207). In this study, these techniques were applied and demonstrated through explaining both the data collection and the methods of data analysis thoroughly and systematically. The video data were listed (see Appendix 2) and the transcriptions, including both verbal and nonverbal activities, were done in detail so that a reader could follow the process of data analysis.

In qualitative research, ethical issues often emerge from data collection (Merriam, 1998, 213). In this study, video recordings were chosen as the method of data collection. The benefits of video material and interaction analysis are that the material can be viewed an unlimited number of times and by multiple investigators (Jordan & Henderson, 1995, 52). Video recordings enable a researcher to collect large amounts of detail when comparing to a human observer (Derry et al., 2010, 16). However, Derry and others (2010, 16) go on to state that large amounts of data are challenging and time-consuming to work with. In this study, not all of the videos that were filmed could be analyzed and data condensation was used to find the meaningful intervention episodes. Another challenge with visual media e.g. video data are the issues of privacy and anonymity that are considerably larger than with some other data forms (Miles et al., 2014, 63). To protect the anonymity of the participants, details of the researched school were

told at a general level. The name of the school in the curriculum document was anonymized and the names of all teachers and students were changed.

The data collection of this study was conducted together with the research group, consisting of seven people. Since a few different people collected the data, this can have an effect on reliability. Different researchers in our group have different research interests so they might have unintentionally focused on videoing events more suitable for their own topic. However, we tried to prevent this by allocating at least one camera to follow a teacher and one to film either a group of students or a single student. If we were able to have all four cameras in use, we would follow two teachers and film two students/student groups. This depended on how many researchers were available to film the lessons on given days. As video data is becoming increasingly popular in educational research, it is important to focus on the ethical considerations of video material especially how easy it is to share and access the data (Derry et al., 2010, 40).

Researching people and especially children raises many ethical questions. For example, who is responsible for deciding whether a child is allowed to participate in a research study? Collecting and analyzing video material brings on different ethical questions as compared to interviews or field observations. When videoing is a part of data collection, it is ethically required to ask for filming permission from the participants and to explain the purpose for which the videos will be used (Pink, 2007, 364). In this research, each teacher and student were asked for permission to participate in the study. Since all students were minors, the permission was given by a responsible third party, in this case the students' legal guardians (Derry et al., 2010, 35). Each student also had the possibility to refuse being filmed during the lessons. It should also be noted that since the participating school held FUSE lessons only for 4th, 5th and 6th graders, this research can only produce information about teacher interventions in regard to 9 to 12-year-old students. Intervention strategies and situations might differ when teaching younger or older students.

The communication of the teachers and students is presented in the original language (Finnish) and not only as a translation made by the researcher, which improves the ethicality (Nikander, 2010, 439). This technique is referred to as parallel translation that improves the transparency of the analysis by allowing readers who know both languages to evaluate the translations (Nikander, 2010).

9 Discussions and conclusions

This chapter will discuss the results of this study and compare them to previous research. The research questions of this study related to teacher interventions in students' joint work, specifically the kind of situations where teachers intervene and the intervention strategies teachers use when intervening. Conclusions can be drawn from this research by analyzing which situations in a novel learning environment required teacher interventions and which intervention strategies teachers used when intervening in students' joint work in a novel design and making environment. Finally, limitations of this study as well as suggestions for further research will be presented.

The researched school had implemented a novel design and learning environment called the FUSE Studio as a way to respond to new learning objectives in the new Finnish National Core Curriculum. The teacher interventions were researched by analyzing the video data and using purposeful sampling to discover meaningful intervention episodes. The results indicate that teachers intervene in students' joint work in response to five main scenarios and use features of all three intervention strategies, depending both on the intervention category and on the teacher.

9.1 The content of teacher interventions

One of the goals of this study was to analyze the situations in which teachers intervene in students' joint work. As explained in the summary of the results, five categories were found concerning the situations in which teachers intervene. The categories included STEAM-challenge related, disciplinary, material related, technology related, and motivation related interventions. This information can be utilized if implementing FUSE or a similar learning environment into schools. While disciplinary and motivation related teacher interventions seem unavoidable, challenge, material or technology related teacher interventions could be diminished by studying the intervention episodes of this research and preparing with sufficient teacher and material resources.

This study modelled the intervention strategies after Hofmann and Mercer's research (2016) on teacher interventions in secondary mathematics and science lessons. Unlike in Hofmann and Mercer's study (2016) where they researched why teachers intervened in groups, this study included both teacher and student initiated interventions. Since it has previously been found that some students avoid seeking help in the classroom (Ryan, Pintrich and Midgley, 2001), it was crucial for this research to determine whether help was given only to students who approached teachers or also to students who did not do so. Hence, all the interventions were divided into teacher initiated or student initiated intervention episodes. It was discovered that while a small majority of the interventions were student initiated (60% of all analyzed interventions) teachers also initiated interventions. If this study had focused solely on analyzing teacher initiated interventions, a majority of teacher interventions would have been left unanalyzed. By including both student and teacher initiated interventions, this study was able to provide a wider image of the situations where interventions occurred as well as the intervention strategies teachers used. The ratio of student (60% of all interventions) and teacher (40% of all interventions) suggests that students would seek help independently while teachers would also intervene in groups to check on their progress and help with group processing. Also Chiu (2004) has identified that while students may seek help to stay on-task, a teacher should initiate interventions as well since not all groups ask for help when encountering a problem and are then more likely to be driven off-task. The ratio of student and teacher initiations depended on the category of the intervention. Challenge, material, and technology related interventions were initiated by students, while most of disciplinary and all of motivation related interventions were initiated by teachers.

Some students in student pairs or groups seemed to be more active in seeking help. Earlier research suggests that some students are active in help-seeking, while some avoid it altogether (Ryan, Pintrich & Midgley, 2001). Often a teacher received multiple requests, occasionally simultaneously, if he or she seemed approachable. Teacher's approachability is important in help-seeking since a student may not seek help if they feel that it is not effective if the helper seems incompetent or if it takes too long to get help (Ryan, Pintrich & Midgley,

2001). However, teachers would often first encourage students to find the information in order to solve the problem independently. Material requests were an exception, since teachers tended to solve them in the students' behalf. This suggests that teachers can still improve sharing the responsibilities with students, who would ideally demonstrate ownership within their own learning and also be responsible for the materials and workspaces (Penney, 2016, 4).

The results produce a variety of examples of the kind of situations that require a teacher intervention in implementing the FUSE Studio into a school. For example, it seemed that the teacher resources were not always adequate and the teachers might feel bad over having to help multiple groups at a time (Example 4). In addition, some materials and translation problems took up a lot of the teachers' time and it would be interesting to see whether the ratio of STEAM-challenge related interventions would be larger in schools where FUSE has been used for longer periods of time. The results of this study can be utilized when developing the FUSE program further as well as when implementing it into new schools and other locations.

9.2 Intervention strategies and supporting relative expertise

Another goal of this study was to analyze the intervention strategies teachers use when intervening in students' joint work. This was done by focusing on the intervention episodes that had further interactions between teachers and students after the initial intervention. This decision was similar to Hofmann and Mercer's study (2016, 405) where they ruled out occasions where a teacher would check on the group work and no further interactions would follow.

Teachers have been found to resort to authoritative strategies especially when none of the students know how to proceed (Ding et al., 2007). Similar results were found in this study, when teachers would guide students step by step if they were doing something for the first time. Although teachers were found using authoritative strategies, these should not automatically be seen as inferior to other strategies. Authoritative strategies were used quite systematically by teachers in situations where the task was completely new to the student e.g. uploading pictures (example 10) or using a new software (example 11). However, what

should be considered is which situations present a need for authoritative strategies in this kind of novel learning environment. Since disciplinary situations were found to be authoritative by nature, could a teacher be taught to consciously use initiating and continuing interactive strategies in for instance STEAM-challenge or technology related interventions? Supporting more interactive approaches and peer resources has been found to have positive effects on both successful problem solving and students' thinking skills (Chiu, 2004; Ding et al., 2007; Johnson & Johnson 2002).

Hofmann & Mercer (2016) defined the second strategy as teacher initiating interactions within a fixed group of students. In this study, the initiated interaction did not necessarily have to stay within one group. One of the teachers especially, John, tried to create practices that would define how the students behaved and learned within the entire learning environment. These attempts were visible in both initiating and continuing interactive strategies. By inviting students to help each other and ask advice from each other, he intended to strengthen relative expertise and emphasize the teacher's role as more of facilitator. This is consistent with the FUSE program's goal of developing relative expertise (Stevens et al., 2016; Penney, 2016). A teacher could for example bring together the expert student and the one with the problem (example 13). In the same example, the teacher also recognized one student as an expert by borrowing the teacher's own expertise to the student and encouraging others to ask the student for help, instead of the teacher. Champion, Penney and Stevens (2016) agree that teachers, as well as other students, can recognize students as relative experts.

While recognizing students as experts is an effective learning resource in encouraging peer collaboration, promoting a teacher as an expert can sometimes have the opposite effect. This was demonstrated in example 11, where teacher Beth asked teacher Greg to help with a software problem. It seemed that while being considered an expert, teacher Greg resorted to authoritative strategies. In another example, a different teacher asked for Greg's help and as a result, the continuing interactive strategies of that intervention turned into authoritative (example 14). Because of his expert position, the teacher also seemed unwilling to admit to mistakes he made, even when the students would point out the errors.

As the results demonstrate, promoting a teacher's expertise reinforces their traditional expert teaching style of transmitting knowledge (Grasha, 1994). This contradicts with FUSE's research base, which emphasizes that teachers do not need to be experts and instead, should maintain a novice position alongside their students (Penney, 2016). It should be considered that in some teacher interventions authoritative strategies were justifiable e.g. in disciplinary situations or guiding students through a technical task for the first time. However, authoritative approaches challenge efforts for promoting collaborative problem solving since earlier research makes evident that successful problem solving needs to include student processing (Johnson & Johson, 2002).

A new feature of both initiating and continuing interactions strategies was how systemically teachers encouraged the students to ask help from each other. This supports previous research, which has indicated that effective intervening needs to combine both teacher and peer resources (Ding et al., 2007). In Hofmann and Mercer's research (2016), peer help was only visible within fixed groups. In this study, help-seeking and interactions could be elicited both within a group, as well as between individual students and larger groups.

The teacher interventions were analyzed based on the intervention strategies. However, the results indicate that certain teachers seemed to use certain strategies. Teacher Greg appeared to have good authority among students' (example 3) and he was likewise found to be using authoritative strategies (examples 10 and 11). Teacher John was found to be applying initiating and continuing interactive strategies in interventions and he seemed to emphasize students' reciprocal collaboration. However, conclusions cannot be drawn about the teachers and their intervention strategies since the examples were analyzed based on the different strategies, not the teachers. Analyzing the frequency of a certain intervention strategy in a specific teacher's work would require further research.

The results of this study indicate that the FUSE program is one possible pedagogical approach through which the new Finnish National Core Curriculum is enacted. The results make evident that authoritative strategies and a teacher's traditional role as a transmitter of knowledge are both still visible in this novel learning environment. It seems that the learning environment does not automatically modify the teacher's role and that further education is required for teachers

to learn how to benefit from all aspects of maker education. However, the initiating and continuing interactive strategies that were visible seemed to immediately support the development of relative expertise and collaborative problem solving between students. Overall, innovative STEAM learning environments have the potential to induce such positive learning effects as long as teachers learn how to change their role according to the objectives of novel learning environments.

9.3 Limitations of this study

One way of evaluating a research study's internal validity is through the number of people who collect and interpret the same data (Merriam, 1998). One limitation of this study is that the intervention episodes were not analyzed by more than one researcher. Originally, interaction analysis was planned as a method for collaborative work groups where videos could be viewed multiple times by multiple viewers (Jordan & Henderson, 1995, 43). Although these data samples of this study were not analyzed by more than one researcher, some of the videos were watched together by the members of the research group. In addition, the content log was discussed and examined together with the group.

The solutions of a teacher intervention were not necessarily captured on film. Hence, it could not always be determined whether a teacher used the same intervention strategy throughout the intervention. Often the camera followed the teacher so the immediate results of the intervention on peer collaboration might not have been evident. However, when teachers returned to the same groups, it would be visible how the students' joint work had progressed or whether they had found solutions to the initial problems collaboratively.

The intervention strategies of eight intervention episodes were analyzed based on Hofmann and Mercer's (2016) earlier research and the three intervention strategies they identified. In a more extensive study, the strategies could have been determined and classified by using data based content analysis. That way, any distinct features concerning the FUSE program and its learning environment would have been more visible in the data. This analytical approach might have created different intervention strategies than Hofmann and Mercer identified in their study. However, even with this directed content analysis the intervention

strategies that were based on earlier research were expanded to include features distinct to FUSE as a design and making environment.

9.4 Suggestions for future research

Important future research questions based on this study are the following: How are problems in similar teacher intervention situations solved? How does the teacher's intervention strategy affect the quality of the solution? In what ways do certain intervention strategies enhance students' learning and relative expertise?

Future research could also aim to create teacher profiles from participating teachers. How could their teaching style be characterized? Do their intervention strategies differ if comparing interventions in FUSE to those in other school subjects? It should also be examined whether the reasons for interventions change when students become more accustomed to working in the learning environment. Do teachers' intervention strategies and teaching styles change the longer they have taught in FUSE? Do students become experts in certain challenges when FUSE lessons progress and do they utilize relative expertise increasingly?

References

Bevan, B., Gutwill, J. P., Petrich, M., & Wilkinson, K. (2014). Learning through STEM-rich tinkering: Findings from a jointly negotiated research project taken up in practice. *Science Education, 99*(1), 98–120.

Bevan, B., Ryoo, J.J., Shea, M., Kekelis, L., Pooler, P., Green, E., Bulalacao, N., McLeod, E., Sandoval, J. & Hernandez, M. (2016). Making as a Strategy for Afterschool STEM Learning: Report from the Californian Tinkering Afterschool Network Research-Practice Partnership. San Francisco, CA: The Exploratorium.

Blikstein, P. (2013). Digital Fabrication and 'Making' in Education: The Democratization of Invention. In J. Walter-Herrmann & C. Büching (Eds.), *FabLabs: Of Machines, Makers and Inventors.* Bielefeld: Transcript Publishers.

Brodie, K. (2000). Teacher intervention in small-group work. *For the Learning of Mathematics*, *20*(1), 9–16.

Champion, D., Penney, L., & Stevens, R. (2016) Developing and recognizing relative expertise in FUSE. In C-K. Looi, J. Polman, U. Cress & P. Reimann. (Eds.). *Transforming Learning, Empowering Learners: The International Conference of the Learning Sciences (ICLS) 2016, Volume 2.* Singapore: International Society of the Learning Sciences. Retrieved from: https://www.isls.org/icls/2016/docs/ICLS2016_Volume_2.pdf

Cohen, J. D., Jones, W. M., & Smith, S. (2018). Preservice and Early Career Teachers' Preconceptions and Misconceptions About Making in Education. *Journal of Digital Learning in Teacher Education*, *34*(1), 31–42.

Dekker, R., & Elshout-Mohr, M. (2004). Teacher interventions aimed at mathematical level raising during collaborative learning. *Educational Studies in Mathematics*, *56*(1), 39–65.

Derry, S. J., Pea, R. D., Barron, B., Engle, R. A., Erickson, F., Goldman, R. & Sherin, B. L. (2010). Conducting video research in the learning sciences: Guidance on selection, analysis, technology, and ethics. *The Journal of the Learning Sciences, 19*(1), 3–53.

Chiu, M. M. (2004). Adapting teacher interventions to student needs during cooperative learning: How to improve student problem solving and time on-task. *American Educational Research Journal*, *41*(2), 365–399.

Ding, M., Li, X., Piccolo, D., & Kulm, G. (2007). Teacher interventions in cooperative-learning mathematics classes. *The Journal of Educational Research*, *100*(3), 162–175.

Erickson, F. (2006). Definition and analysis of data from videotape: Some research procedures and their rationales. *Handbook of complementary methods in education research*, *3*, 177–192.

FNAE. Finnish National Agency for Education. (2014). The new curricula in a nutshell. Retrieved from http://www.oph.fi/english/curricula_and_qualifications/basic_education/curricula_2014. Read 31.5.2017.

Galton, M., & Hargreaves, L. (2009). Group work: still a neglected art?. *Cambridge Journal of Education*, *39*(1), 1–6.

Gee, J.P. Learning and Games. In K., Salen. (Ed.), *The Ecology of Games: Connecting Youth, Games, and Learning.* The John D. and Catherine T. MacArthur Foundation Series on Digital Media and Learning. Cambridge, MA: The MIT Press, 2008. 21–40.

Government Publications. (2015) Finland, a land of solutions - Strategic Programme of Prime Minister Juha Sipilä's Government. Prime Minister's Office Finland. *Government Publications 12/2015*. At http://valtioneuvosto.fi/documents/10184/1427398/Ratkaisujen+Suomi_EN_YHDISTETTY_netti.pdf/8d2e1a66-e24a-4073-8303-ee3127fbfcac. Read 2.8.2017.

Grasha, A. F. (1994). A matter of style: The teacher as expert, formal authority, personal model, facilitator, and delegator. *College teaching*, *42*(4), 142–149.

Halverson, E. R., & Sheridan, K. (2014). The maker movement in education. *Harvard Educational Review*, *84*(4), 495–504.

Hamilton, L. & Corbett-Whittier, C. (2012). Using case study in education research. Sage.

Helsinki by District 2015. (2016). Helsinki: City of Helsinki Urban Facts. Retrivied May 8, 2017 from http://www.hel.fi/hel2/tietokeskus/julkaisut/pdf/16_05_27_Helsinki_alueittain_2015_Tikkanen.pdf

Hilppö, J., Stevens, R., Jona, K., Echevarria, R., & Penney, L. (2016) Productive deviations as manifestations of student agency in FUSE. In C-K. Looi, J. Polman, U. Cress & P. Reimann. (Eds.). *Transforming Learning, Empowering Learners: The International Conference of the Learning Sciences (ICLS) 2016, Volume 2.* Singapore: International Society of the Learning Sciences. Retrieved from: https://www.isls.org/icls/2016/docs/ICLS2016_Volume_2.pdf

Hofmann, R. & Mercer, N. (2016). Teacher interventions in small group work in secondary mathematics and science lessons. *Language and Education*, 30:5, 400–416.

Ito, M., Horst, H. A., Bittanti, M., Stephenson, B. H., Lange, P. G., Pascoe, C. J., ... & Martínez, K. Z. (2009). *Living and learning with new media: Summary of findings from the Digital Youth Project*. MIT Press.

Johnson, D. W., & Johnson, R. T. (2002). Learning together and alone: Overview and meta-analysis. *Asia Pacific Journal of Education*, *22*(1), 95–105.

Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *The Journal of the Learning Sciences, 4*(1)*,* 39–103.

Kovalainen, M., & Kumpulainen, K. (2005). The discursive practice of participation in an elementary classroom community. *Instructional Science*, *33*(3), 213–250.

Kuenzi, J. J. (2008). Science, technology, engineering, and mathematics (STEM) education: Background, federal policy, and legislative action.

Kumpulainen, K. (2017). Makerspaces – Why they are important for digital literacy education. In J. Marsh, K. Kumpulainen, B. Nisha, A. Velicu, A. Blum-Ross, D. Hyatt, . . . G. Thorsteinsson. (Eds.), Makerspaces in the Early Years: A Literature Review (pp. 12–16). University of Sheffield: MakEY Project. Retrieved from http://makeyproject.eu/wp-content/uploads/2017/02/Makey_Literature_Review.pdf

Kumpulainen, K., Kajamaa, A. & Rajala, A. (forthcoming). Motive-demand dynamics creating a social context for students' learning experiences in a making and design environment. In A. Edwards, M. Fleer & L. Bottcher (Eds). Cultural-historical approaches to studying learning and development: societal, institutional and personal perspectives. SAGE Publications Ltd.

Kurti, R. S., Kurti, D. L., & Fleming, L. (2014). The philosophy of educational makerspaces: Part 1 of making an educational makerspace. *Teacher Librarian*, *41*(5), 8.

Marusteru, G. (2017). The history of the maker movement. In J. Marsh, K. Kumpulainen, B. Nisha, A. Velicu, A. Blum-Ross, D. Hyatt, . . . G. Thorsteinsson. (Eds.), Makerspaces in the Early Years: A Literature Review (pp. 17–21). University of Sheffield: MakEY Project. Retrieved from http://makeyproject.eu/wp-content/uploads/2017/02/Makey_Literature_Review.pdf

Meirink, J. A., Meijer, P. C., Verloop, N., & Bergen, T. C. (2009). Understanding teacher learning in secondary education: The relations of teacher activities to changed beliefs about teaching and learning. *Teaching and teacher education*, *25*(1), 89–100.

Merriam, S. B. (1988). *Case study research in education: A qualitative approach*. Jossey-Bass.

Merriam, S. B. (1998). *Qualitative Research and Case Study Applications in Education. Revised and Expanded from" Case Study Research in Education.* San Francisco: Jossey-Bass Publishers.

Miles, M. B., Huberman, A. M., & Saldaña, J. (2014). *Qualitative data analysis: A methods sourcebook* (3. ed.). Los Angeles: Sage.

NCC (2014). National Core Curriculum for Basic Education 2014. Helsinki: The Finnish National Board of Education.

Nikander, P. (2010). Laadullisten aineistojen litterointi, kääntäminen ja validiteetti. Teoksessa J. Ruusuvuori, P. Nikander & M. Hyvärinen. (toim.) *Haastattelun analyysi* (432–445).Tampere: Vastapaino.

Palinkas, L. A., Horwitz, S. M., Green, C. A., Wisdom, J. P., Duan, N., & Hoagwood, K. (2015). Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. *Administration and Policy in Mental Health and Mental Health Services Research*, *42*(5), 533–544.

Penney, L. R. (2016). *An Investigation Into How Students Select and Develop Resources for Learning as They Pursue Choice-Based STEAM Challenges* (Doctoral dissertation). Illinois: Northwestern University.

Penney, L., Jona, K., & Stevens, R. (2016). Learner choice and the emergence of diverse learning arrangements in FUSE. In C-K. Looi, J. Polman, U. Cress & P. Reimann. (Eds.). *Transforming Learning, Empowering Learners: The International Conference of the Learning Sciences (ICLS) 2016, Volume 2.* Singapore: International Society of the Learning Sciences. Retrieved from: https://www.isls.org/icls/2016/docs/ICLS2016_Volume_2.pdf

Peppler, K., & Wohlwend, K. (2018). Theorizing the nexus of STEAM practice. *Arts Education Policy Review*, *119*(2), 88–99.

Pink, S. (2007). Visual methods. In C., Seale, G., Gobo, J.F., Gubrium & D., Silverman. (Eds.), Qualitative research practice (361–376). London & Thousand Oaks: SAGE.

Ramey, K. E. (2017). FUSE Studios: Bringing Interest-driven, Integrated-STEAM Learning into Schools via Makerspaces. (Doctoral dissertation, Northwestern University).

Ryan, A. M., Pintrich, P. R., & Midgley, C. (2001). Avoiding seeking help in the classroom: Who and why?. *Educational Psychology Review*, *13*(2), 93–114.

Savery, J. R., & Duffy, T. M. (1995). Problem based learning: An instructional model and its constructivist framework. *Educational technology, 35*(5), 31–38.

Sheridan, K., Halverson, E. R., Litts, B., Brahms, L., Jacobs-Priebe, L., & Owens, T. (2014). Learning in the making: A comparative case study of three makerspaces. *Harvard Educational Review*, *84*(4), 505–531.

Stevens, R. & Jona, K. (2017a). Our research. FUSE Studio -website. Retrieved May 20, 2017 from https://www.fusestudio.net/our-research

Stevens R. & Jona, K. (2017b) Program Design. FUSE Studio -website. Retrieved May 20, 2017 from https://www.fusestudio.net/program-design

Stevens, R., Jona, K., Penney, L., Champion, D., Ramey, K., Hilppö, J., Echevarria, R. & Penuel, W. (2016). FUSE: An Alternative Infrastructure for Empowering Learners in Schools. In C-K. Looi, J. Polman, U. Cress & P. Reimann. (Eds.). *Transforming Learning, Empowering Learners: The International Conference of the Learning Sciences (ICLS) 2016, Volume 2.* Singapore: International Society of the Learning Sciences. Retrieved from: https://www.isls.org/icls/2016/docs/ICLS2016_Volume_2.pdf

Tran, N. A. (2011). The Relationship between Students' Connections to Out-of-School Experiences and Factors Associated with Science Learning. *International Journal of Science Education*, *33*(12), 1625–1651.

Yackel, E., Cobb, P., & Wood, T. (1991). Small-group interactions as a source of learning opportunities in second-grade mathematics. *Journal for Research in Mathematics Education*, 390–408.

Appendix 1: The FUSE Studio Challenges

3D You

Create a 3D model of yourself and print it out on the 3D printer!

Coaster Boss

Can you build the fastest roller coaster in FUSE?

Cookie Customizer

Design and print unique cookie cutters, make awesome cookies, and then eat them.

Crystal Ball

Fade and Flash combinations of Red, Green, and Blue LED lights - program them to create a fantastic light display!

Dream Home

Design your dream home in 3D.

Dream Home 2: Gut Rehab

Take on the role of an architect! Choose between redesigning a family home or renovating a teen center.

Electric Apparel

Customize your clothing and accessories so that they light up when you use them.

Eye Candy

Design your own glasses and print them out!

Game Designer

Use video game design tools to help your hero beat the game!

Get in the Game

Design controllers for online gamers that make the game more fun and interactive.

How to Train Your Robot

Train a Sparki robot to walk, bark, draw, and fetch treats!

Jewelry Designer 2.0

Design your own jewelry and print it out in 3D! Create custom necklaces and earrings!

Just Bead It!

Create gel beads using the same cutting-edge techniques scientists use to grow human cells.

Keychain Customizer

Design and 3D print a keychain with your name or custom message!

Laser Defender

Create a laser beam security system to protect a valuable ”treasure” and challenge your friends to break in!

LED Color Lights

In this challenge, combine and control light from three LEDs to produce a rainbow of different colors.

Mini Jumbotron

Fill up a screen with text, images, and games!

MiniMe Animation

Use 3D animation software to bring a CGI figure to life! Customize their colors, give them expressions, and make them dance!

Music Amplifier

Build an amp for your phone, mp3 player, or computer!

Party Lights

Build a light display that blinks and fades in a pattern of your own design.

Print My Ride

Design your own model car and then print it out in 3D complete with rolling wheels.

Ringtones

Mix your own custom ringtone! Note: This new version uses a different audio mixing software and has new levels.

Robot Obstacle Course

Can you make a robot navigate through the sharp turns, bridges, and lava?

Selfie Sticker

Make a sticker self-portrait!

Smart Castle

Upgrade a toy castle with clap on/off lightning, intruder alerts, and more!

Solar Roller

Master the racetrack by getting your solar powered car through tunnels, distance tests, and more!

Solar Roller Showcase

Can you set the record for the fastest 60 inch dash with your Solar Roller car?

Spaghetti Structures

Can you break the record for the tallest tower?

Wind Commander

Harness the power of the wind to lift weight, make electricity, and turn on lights!

Appendix 2: List of video data

Date	Content	Length (h:mm:ss)
1.9.2016	Teacher video	0:37:56
1.9.2016	Student choosing a challenge	0:05:26
1.9.2016	**Teacher video**	**0:23:01**
2.9.2016	***Dream Home:* Two girls in the computer classroom**	**0:25:01**
2.9.2016	Teachers discussing at the end of the lesson	0:13:00
2.9.2016	Researchers and teachers discussing	0:14:41
2.9.2016	Students working in the computer classroom	0:41:32
2.9.2016	*Spaghetti structures:* Three girls in the classroom	0:46:16
2.9.2016	***Coaster Boss:* Three boys in the hallway**	**0:31:22**
8.9.2016	***Solar Roller:* Four girls in the classroom**	**0:43:21**
8.9.2016	Teacher video	0:46:37
8.9.2016	**Teacher video**	**0:35:52**
8.9.2016	**Teacher video**	**0:40:44**
8.9.2016	**Teacher video**	**0:45:46**
8.9.2016	*Dream Home:* Three boys and one girl in the computer classroom, separate computers	0:40:49
8.9.2016	Teachers discuss FUSE	0:02:52
8.9.2016	**In the hallway: *Spaghetti Structures:* Two boys; *Coaster Boss*: Six boys; *Coaster Boss:* Two boys**	**0:37:51**
8.9.2016	Teachers and researcher discuss FUSE	0:08:18
8.9.2016	*Solar Roller:* Three boys in the hallway	0:29:04
9.9.2016	**Teacher video**	**0:58:25**
9.9.2016	Researcher interviews a teacher	0:03:16
9.9.2016	*Ringtones*: One boy in the computer classroom	0:50:47
9.9.2016	Teacher video	0:49:51
9.9.2016	Students working in the classroom	0:22:05
9.9.2016	*Lazer Defender:* One boy in the hallway; *Coaster Boss:* Two boys in the hallway	0:55:39

15.9.2016	**Teacher video**	**0:58:56**
15.9.2016	Teacher video	0:36:52
15.9.2016	***Electric Apparel:* Two girls in the computer classroom**	**1:04:12**
15.9.2016	**Teacher video**	**0:47:55**
15.9.2016	**Teacher video**	**0:56:29**
15.9.2016	Teachers discuss FUSE	0:02:33
15.9.2016	***Dream Home*: One girl and one boy in the computer classroom, separate computers**	**0:45:51**
15.9.2016	***Coaster Boss:* Two boys in the hallway**	**0:48:52**
15.9.2016	*Spaghetti Structures*: Two boys in the classroom	0:23:42
15.9.2016	*Coaster Boss*: One boy in the classroom	0:15:10
16.9.2016	**Teacher video**	**0:53:34**
16.9.2016	***Spaghetti Structures:* Two girls in the classroom**	**0:54:57**
16.9.2016	Researcher interviews teachers	0:04:44
16.9.2016	**Teacher video**	**0:59:28**
16.9.2016	*Coaster Boss:* Three pairs of two boys in the hallway	1:00:12
22.9.2016	**Teacher video**	**0:56:19**
22.9.2016	Reporter interviews a teacher	0:05:44
22.9.2016	**Teacher video**	**1:00:00**
22.9.2016	***Jewelry Designer*: Two pairs of two girls in the classroom**	**0:50:56**
22.9.2016	***Dream Home:* One girl in the computer classroom**	**0:53:24**
22.9.2016	Teachers and researchers discuss FUSE (ota pois 65-1)	0:19:44
22.9.2016	**Teacher video**	**0:56:05**
22.9.2016	**Teacher video**	**0:52:09**
22.9.2016	***Coaster Boss:* Six boys in the hallway**	**0:52:44**
22.9.2016	*Ringtones:* Four girls in the classroom, separate laptops	0:19:10

22.9.2016	*Solar Roller:* Two girls and one boy in the hallway	0:32:40
23.9.2016	**Teacher video**	**0:51:58**
23.9.2016	Teachers and researcher discuss FUSE	0:31:31
23.9.2016	*Coaster Boss:* Two boys in the hallway	0:42:54
23.9.2016	Teacher video	0:55:57
23.9.2016	Researcher interviews teachers	0:30:56
23.9.2016	*Laser Defender:* One boy in the hallway; *Spaghetti Structures:* Two boys in the hallway	0:22:27
23.9.2016	*Coaster Boss:* Two girls in the classroom	0:26:33
29.9.2016	**Teacher video**	**0:55:16**
29.9.2016	**Teacher video**	**0:39:57**
29.9.2016	*Music Amplifier:* Two boys in the computer classroom	0:52:41
29.9.2016	Teacher video	0:41:45
29.9.2016	Teacher video	1:04:55
29.9.2016	Teacher video	0:50:00
29.9.2016	*Coaster Boss:* Four boys in the hallway	0:55:35
29.9.2016	*Laser Defender:* Two boys in the hallway	0:42:45
30.9.2016	***Electric Apparel:* Two girls in the classroom -> Third girl join and they change to *Spaghetti Structures***	**0:56:33**
30.9.2016	Researcher interviews two students	0:09:56
30.9.2016	**Teacher video**	**1:00:25**
30.9.2016	**Teacher video**	**0:56:27**
6.10.2016	**Teacher video**	**0:59:12**
6.10.2016	Researcher interviews a teacher	0:01:02
6.10.2016	***Dream Home:* Two boys in the computer classroom, separate computers**	**0:40:58**
6.10.2016	***Coaster Boss:* Four boys in the hallway**	**0:58:15**
6.10.2016	**Teacher video**	**0:48:44**
6.10.2016	**Teacher video**	**0:56:27**
6.10.2016	Teacher video	0:53:26
6.10.2016	***Coaster Boss:* Four boys in the hallway**	**0:56:19**
6.10.2016	*Laser Defender:* Two girls in the hallway	0:43.13

13.10.2016	**Teacher video**	**1:02:26**
13.10.2016	**Teacher video**	**0:42:46**
13.10.2016	Teacher video	0:43:05
13.10.2016	Researcher interview the school principal	0:03:00
13.10.2016	Discussion between a teacher and a student	0:08:16
13.10.2016	Researcher interviews teachers	0:02:35
13.10.2016	*Coaster Boss:* Four girls in the hallway	0:49:43
13.10.2016	*Solar Roller:* Four boys in the hallway; *Coaster Boss:* Four boys in the hallway	0:42:46
13.10.2016	Teacher video	0:03:18
13.10.2016	Teacher video	0:41:32
14.10.2016	**Teacher video**	**0:57:30**
14.10.2016	Teacher video	0:52:11
14.10.2016	Teacher discussion at the end of the lesson	0:07:45
27.10.2016	**Teacher video**	**1:01:08**
27.10.2016	**Teacher video**	**0:34:02**
28.10.2016	**Teacher video**	**0:58:11**
3.11.2016	**Teacher video**	**0:46:55**
3.11.2016	**Teacher video**	**0:25:14**
3.11.2016	*Laser Defender*: Two girls in the hallway	0:25:44
4.11.2016	**Teacher video**	**1:01:24**
4.11.2016	*Music Amplifier:* One boy in the classroom	1:02:31
4.11.2016	*Laser Defender*: Three boys and one girl in the hallway	0:57:23
10.11.2016	***MiniMe Animation*: Three girls in the computer classroom, separate computers**	**0:46:20**
10.11.2016	**Teacher video**	**0:50:37**
11.11.2016	**Teacher video**	**0:58:27**
17.11.2016	**Teacher video**	**0:38:44**
17.11.2016	**Teacher video**	**0:50:37**
18.11.2016	**Teacher video**	**0:56:43**
24.11.2016	**Teacher video**	**0:56:28**
24.11.2016	**Teacher video**	**0:45:49**
24.11.2016	**Teacher video**	**0:54:59**
24.11.2016	**Teacher video**	**0:53:51**

24.11.2016	*Wind Commander:* Two boys in the hallway	0:05:57
24.11.2016	Students working in the classroom	0:41:57
24.11.2016	*Dream Home:* One girl in the computer class	0:43:38
24.11.2016	*Wind Commander:* Four boys in the hallway	0:40:39